An Examination of the Modified Water Deliveries Project, the C-111 Project, and the Experimental Water Deliveries Project: Hydrologic Analyses and Effects on Endangered Species

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January 1999

Acknowledgements

A number of technical reviews provided comments which greatly improved this document. The authors wish to thank Dr. Stuart Pimm, John Ogden, Dr. Frank Mazzotti, and Heather McSherry for their comments on the ecological analyses. Dr. Rob Bennets contributed advice and direction to the snail kite analysis. We are grateful to Susan Bullock, Jose Otero, Cal Neidrauer, Ray Santee, Dr. Jayanatha Obeysekera, Dr. Ken Tarboton, Dr. Eric Swain, Dr. Reza Savabi, Lewis Hornung, Linda McCarthy, Molly Sandfoss, Thomas MacVicar, and Kevin Kotun for their constructive criticisms regarding the hydrologic analyses.

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Introduction

The Everglades National Park has as one of its primary management objectives the preservation and restoration of sustainable Everglades ecosystems [Everglades National Park, 1993]. The South Florida Natural Resources Center (SFNRC) at Everglades National Park is charged with reviewing and assessing appropriate information on the status and trends of the natural resources on Park Service lands to determine if progress towards this objective is being made. Moreover, the SFNRC is actively participating in interagency efforts to bring about ecosystem restoration. This report provides information about the Program of Experimental Water Deliveries to Everglades National Park, the Modified Water Deliveries, and the C-111 Project relevant to National Park Service objectives for hydrologic and ecologic restoration of Everglades National Park. In addition, the report represents the efforts of the National Park Service to provide some technical assistance as part of the U.S. Fish and Wildlife Service's reconsultation pursuant to Section 7 of the Endangered Species Act (16 U.S.C. 1536).

This report is primarily focused on the hydrologic aspects of Experimental Water Deliveries, Modified Water Deliveries Project, and the C-111 Project relevant to the endangered species most likely to be affected by these projects: Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*), the snail kite (*Rostrhams sociabililis plumbeus*), the wood stork (*Mycteria americana*), the American crocodile (*Crocodylus acutus*), and the manatee (*Trichechus manatus latirostris*). Since these three projects are water resources management projects, the analysis is focused on the hydrologic effects related to the above five species.

This report not intended to be an exhaustive examination of hydrologic effects of the Experimental Water Deliveries Program or the Modified Water/C-111 Projects. Rather, we have applied hydrologic simulation models to analyze the possible effects of these projects. The limited time precluded more extensive analyses of the available hydrologic and ecologic data.

1.1 Objectives

The scope of this report is limited to an examination of the area shown in Figure 1. The area examined includes Everglades National Park, the Big Cypress National Preserve, Water Conservation Area 3B, southern Water Conservation Area 3A, and to a limited extent, southern Miami-Dade county.

The objectives for this report are as follows:

- Model the hydrology of south Florida with and without each of the projects being evaluated.
- Determine the effects of Experimental Water Deliveries, Modified Water Deliveries, and the C-111 Project on the Cape Sable seaside sparrow, the wood stork, the snail kite, the crocodile, and the manatee.
- Examine actions which could improve conditions for the Cape Sable seaside sparrow, the wood stork, the snail kite, the crocodile, and the manatee.
- Analyze performance and overall hydrologic effects of the Experimental Water Deliveries Program, the Modified Water Deliveries Project, and the C-111 Project.

The report is organized according as follows. Following an introductory chapter, the Experimental Water Deliveries Program is examined in Chapter 2. Included therein are descriptions of the computer simulations and presentation of the effects on endangered species. Several alternatives which may improve the Experimental Water Deliveries Project are presented in Chapter 3. Modified Water Deliveries and the C-111 Project are examined together in Chapter 4. Included are descriptions of the simulations, an analysis of the hydrologic characteristics of Modified Water Deliveries/C-111, and an examination of the effects of Modified Water Deliveries/C-111 on endangered species.

Figure 1: General location map.

1.2 Background on Listed Species

1.2.1 Cape Sable Sparrow

The Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*) was listed as an endangered subspecies in 1967. It is a medium-sized sparrow that occurs in Miami-Dade and Monroe Counties of South Florida. This non-migratory sparrow has the most restricted range of any bird in North America and occurs almost exclusively within the boundaries of Everglades National Park and Big Cypress National Preserve.

Recent field studies conducted by the National Park Service and Dr. Stuart L. Pimm of the University of Tennessee have documented the Cape Sable seaside sparrow's sharp decline in numbers and have identified the causes of the decline. The background information that follows draws from the principle results of these studies as documented in *The 1997 Annual Report on the Cape Sable Seaside Sparrow* [Pimm, 1997] and expounded in two scientific papers appearing recently in the new international journal *Animal Conservation* (Curnutt *et al.* [1998] and Nott *et al.* [1998]). Much of what follows has appeared in *Balancing on the Brink: The Everglades and the Cape Sable Seaside Sparrow* [U.S. Fish and Wildlife Service and U.S. National Park Service, 1997]. For additional background information and literature, the reader is also referred to *Remedial Actions and Alternative Management Interventions for Protection of the Cape Sable Seaside Sparrow During Test Iteration 7 of the Experimental Program of Water Deliveries to Everglades National Park* [U.S. Fish and Wildlife Service, 1998b] and the Multi-species Recovery Plan for the Threatened and Endangered Species of South Florida [U.S. Fish and Wildlife Service, 1998a].

The extent and distribution of the Cape Sable seaside sparrow has changed dramatically in the last century. South Florida has the largest expanse of marl prairie, the preferred habitat of the sparrow. These prairies are naturally inundated on average from 3 to 7 months per year (from approximately July through January), but are dry during the sparrow's breeding season (March through June). This expanse of potential sparrow habitat has suffered two major assaults within this century: drainage and development. In South Florida, marl prairies have been lost to agricultural and urban land uses and are no longer suitable for the sparrows. Moreover, the construction of canals throughout the Everglades ecosystem has altered the hydrological regime of much of the remaining marl prairies. Much of the remaining prairies are rendered unsuitable for the sparrows because changes in the hydrology have initiated changes in dominant vegetation. Areas that have been flooded

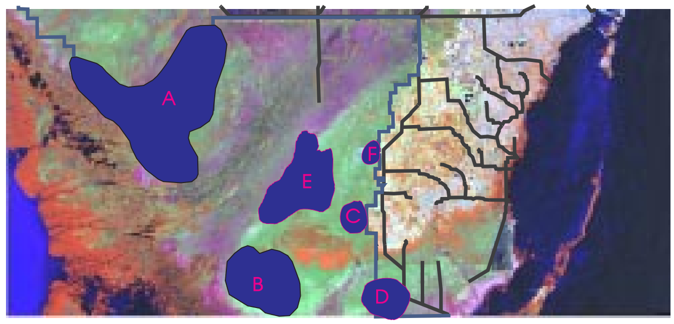


Figure 2: The location of the six subpopulations of the Cape Sable sparrow, after Curnutt and Pimm [1993].

for longer periods than are normally appropriate for marl prairies are shifting from grassy marshes to sawgrass marshes. Prairies flooded for shorter periods of time are experiencing the spread of woody plants.

The suitability of this vegetative community for the sparrow appears to be the result of a combination of hydroperiod and periodic fires. Fires prevent hardwood species form invading these communities and prevent the accretion of dead plant material, both of which decrease the suitability of these habitats for Cape Sable seaside sparrows.

As in many other seaside or savannah sparrows, male Cape Sable seaside sparrow occupy and defend their territories during the breeding season (March through June). Breeding activity, particularly singing behavior by males, appears to decrease with increased surface-water conditions. Nests are cups constructed of grasses and are approximately 4 inches above the ground. When water levels exceed 4 inches, nesting activities cease.

The entire Cape Sable seaside sparrow population exists as six subpopulations. Two core populations (one to the northwest of Shark Slough in Everglades National Park and Big Cypress National Preserve, and one to the southeast of Shark Slough in the vicinity of the Old Ingraham Highway) held the majority of sparrows before 1993. Sparrows in four other smaller peripheral locations to the east and northeast of Shark Slough hold small and variable numbers of sparrows. Figure 2 shows the location of the six subpopulations of the Cape Sable sparrow (after Curnutt and Pimm [1993]). As seen in Table 1, as recently as 1992, subpopulations A and B represented core populations. Subpopulation A now represents only 7% of the total population and no longer functions as a core population, while it had represented 41% in 1992. Sparrows in two of the four peripheral locations went locally extinct between 1992 and 1995 but were recolonized by small numbers in 1996.

Overall, however, the Eastern peripheral subpopulations in total (C, D, E and F) have not recovered to their 1981 level. Unusually high water levels in 1993, 1994, and 1995 are the cause of the decline in subpopulation A. High water levels were a result of heavy rain in combination with releases of flood waters into Everglades National Park from reservoirs north of the park. Large releases from upstream reservoirs were most responsible for the bird's precipitous decline west of Shark Slough in subpopulation A [Nott *et al.*, 1998]. A detailed study of the sparrow's breeding biology by Lockwood *et al.* [1997] shows that surface water depths greater than 4 inches halts breeding activity. Changes in the vegetation where subpopulation A is located also occurred during this period and made the marl prairies west of Shark Slough less suitable for the sparrow. An increase in hydroperiod favors sawgrass. Sparrows do not inhabit areas dominated by sawgrass or open water.

Subpopulations C through F have held small and variable numbers of sparrows since 1992. The total number of sparrows in these (C–F) subpopulations has declined since 1981 and remained at lower numbers than one would expect on the basis of the year-to-year variability of grassland sparrows, indicating that the birds have not recovered to their former range. The causes of the decline in these eastern subpopulations (C–F) is likely directly related to fire, and indirectly to overdrainage. Taylor [1981] found a high correlation between water levels and number of fires in the Park. Fire forces the sparrows to abandon territories and, if too frequent, makes the habitat unsuitable. Sparrow densities are highest in sites that burned once or twice in a ten year period, and approached zero in sites that burned seven or more times in that period. The local extinctions from parts of the eastern habitats are likely due to the high incidence of arson fires along the eastern boundary of Everglades National Park.

These heavily burned areas are today much drier than historical water patterns would suggest. Water that historically flowed through Shark Slough is diverted away from the eastern subpopulations, leaving them drier. Moreover, canals just to the east of the Everglades National Park keep the area dry year-round, permitting a high and detrimental fire frequency.

As discussed and illustrated by the U.S. Fish and Wildlife Service and U.S. National Park Service [1997], the implications of these subpopulation declines are alarming. In an assessment of the risk of extinction for the Cape Sable seaside sparrow, Pimm [1997] performed separate risk analyses for each of the three areas, subpopulation A, B, and the collective subpopulations of C–F. Computer simulations indicate that subpopulation A will decline further and eventually to extinction if the pattern of managed water flows for the

Subpopulation	Year							
	1981	1992	1993	1994	1995	1996	1997	1998
A	2688	2608	432	80[a]	224	400	272	192
B	2320	2992	2416	2176	2048	2048	2784	1808
C	433	48	0	-	0	48	48	64
D	400	112	96	-	0[b]	80	48	48
E	672	592	320	112	352	192	752	928
F	112	0	0	-	0	16	16	16
Total	6624	6352	3264	2368	2624	2784	3920	3056

[a] Logistical problems resulted in an incomplete survey. Totals for year reflect these incomplete surveys.
[b] As above.

Table 1: The estimated number of breeding Cape Sable seaside sparrows in each area for each year. Sparrow numbers are estimated by multiplying the actual number of birds observed by the Bass and Kushlan [1982] correction factor ($\times 16$).

last 20 years repeats itself. In total, subpopulations C–F have declined to near extinction and will continue unless the fire regimes are changed. As an isolated core, subpopulation B will slowly decline to extinction because of episodic large-scale fires. Pimm [1997] concludes his risk assessment by noting that without changes in current fire and water management practices, the Cape Sable seaside sparrow will become extinct.

1.2.2 Wood Stork

The wood stork (*Mycteria americana*) is a long-legged wading bird of marshes, cypress swamps, and mangrove swamps reaching the northern limit of its breeding range in the southeastern U.S. The unique feeding method of the wood stork, tactolocation (or grope feeding), gives it specialized habitat requirements. Because of its specialized feeding method and the requirement for larger sizes of fishes, the reproductive success of the wood stork corresponds to the availability of specific foraging conditions. The habitats on which wood storks depend have been disrupted by changes in the distribution, timing, and quantity of water flows in South Florida. During wet years, current water management practices prevent the formation of shallow pools that concentrate the fish on which wood storks forage. During dry years, current water management practices overdrain the freshwater sloughs, reduce freshwater flows into the mainland estuaries and reduce their ability to produce the fish on which wood storks forage. The population declines that accompanied this disruption led to its listing as an endangered species and continue to threaten the recovery of this species in the U.S. [U.S. Fish and Wildlife Service, 1998a].

The wood stork performance measure proposed by Ogden [1998] for use by Southern Everglades Restoration Alliance (SERA) and the C&SF Restudy Project evaluations provides the following relevant background information. The number of wood storks nesting in colonies in the central and southern Everglades has declined from 5,000-8,000 birds prior to the C&SF Project (numbers are for 1931–1946) to 250-1,000 birds since 1986 [Ogden, 1991,1994; Gawlik and Ogden, 1996]. During this same spread of years (1931–1986) the timing of colony formation (initiation of nesting) by storks has shifted from November and December for most years prior to 1970 to February and March for most recent years [Ogden, 1994]. Earlier forming colonies were larger and more successful than late forming colonies (e.g. means of 2,250 pairs in November colonies, and 450 pairs in March colonies; successful in 7 of 9 years between 1953-1961, but successful only 6 of 28 years between 1962–1989). Early forming colonies were located almost entirely within the mainland, mangrove forest zone downstream from the freshwater Everglades drainage, or along the mangrove-freshwater ecotone in the southern Everglades. Recent stork colonies mostly have been located on willow and pond apple islands in the south-central Everglades.

Ogden [1994, 1998] proposes that the hypothesis which best explains the changes in nesting patterns by wood storks is that, as a result of substantial reductions in freshwater flow into the mainland estuaries, the production and availability of size classes of fishes which are essential prey for nesting storks has deteriorated to the point where the mangrove zone can no longer support nesting by storks. Ogden [1998] suggests that storks now "wait" until water levels in the later-drying interior sloughs drop low enough for fish to be adequately concentrated to support nesting activity. Interior, late-forming colonies often fail because, (a) fish stocks also are relatively low because of increased frequencies of slough dry-outs in the managed system, (b) interior colonies lack the range of foraging habitat conditions found in estuarine systems, and (c) late colonies are still active when summer rains disperse local prey concentrations.

Ogden [1998] suggests that to recover healthy, sustainable nesting colonies of wood storks in the Everglades basin, storks must return to nesting in the area of the mainland estuaries, with colonies forming no later than January. According to Ogden [1998] the historical pattern was for wood storks to forage primarily in the mainland estuarine region during the early dry season at the time of colony formation, and to forage in the drying freshwater sloughs during the later dry season during the nestling and fledgling stages of reproduction.

1.2.3 Crocodile

The American crocodile (*Crocodylus actutus*) is a Federally-listed endangered species at the northern limit of its range in Florida. The crocodile population in Florida, although small, appears stable or increasing slightly. The American crocodile is considered a valuable indicator species of the health of South Florida's estuarine environment. The American crocodile is found primarily in mangrove swamps and along low-energy mangrove-lined bays, creeks, and inland swamps [Kushlan and Mazzotti, 1989]. In Florida, patterns of crocodile habitat use shifts seasonally. During the breeding and nesting seasons, adults outside of Key Largo use the exposed shoreline of Florida Bay and marl creek embankments. Males tend to stay more inland than the females at this time, whereas during the non-nesting season, they are found primarily in the fresh and brackish-water inland swamps, creeks, and bays; they retreat further into the back country in fall and winter. Along northeastern Florida

Bay, crocodiles are observed mostly in inland ponds, creeks and protected coves, and rarely on exposed shorelines or mud flats. The high use of inland waters suggests crocodiles prefer less saline waters [U.S. Fish and Wildlife Service, 1998a]. Water salinity affects habitat use and may be locally important especially during periods of low rainfall. Although crocodiles have salt glands and physiological mechanisms to reduce water loss, maintenance of an osmotic balance requires access to low salinity water for juveniles. Hatchling crocodiles are particularly susceptible to osmoregulatory stress. Anthropogenic changes in the amount and timing of freshwater flow to South Florida may have resulted in shifts in the distribution of American crocodiles. Unfortunately, detailed data on crocodile distribution is only available since the early 1970s and any changes that may have occurred due to hydrological perturbations over the past century cannot be identified [U.S. Fish and Wildlife Service, 1998a]. Compared to the historical estimates of 1,000 to 2,000 animals [Ogden, 1978a], populations have declined. The lowest estimated population levels appear to have occurred sometime during the 1960s or 70s when the estimated Florida population was between 100 and 400 non-hatchlings [Ogden, 1978b]. According to the U.S. Fish and Wildlife Service [1998a] between 500 and 1,000 individuals (including hatchlings) remain in South Florida today. The population has increased substantially over the last 20 years with the number of nests increasing from about 20 in the late 1970s to about 48 nests in 1995 [U.S. Fish and Wildlife Service, 1998a].

The crocodile population is affected by freshwater inflows into Florida Bay, and to a lesser degree into the Shark Slough estuaries. The main population center is in an area of northeastern Florida Bay likely to affected by C-111 and Taylor Slough projects. Higher salinities are thought to have adverse affects on many components of the Florida Bay ecosystem, including the American crocodile. The survival of crocodiles has been linked with regional hydrological conditions, especially water levels and salinities [Mazzotti 1983, 1989; Moler, 1991]. Young crocodiles attain optimum growth rates in water of 9 ppt [Mazzotti, 1983].

The initial growth period for hatchlings is from August–December, a time when salinities would be reduced in the natural system by increased freshwater flows. The first three months are probably the most critical for hatchling survival. In general the wetter the fall, the better the hatchling survival. However, in recent years salinities exceeding 30 ppt have been regularly recorded in northeastern Florida Bay during August-December [McIvor *et al.*, 1994]. Hatchling crocodiles are particularly susceptible to osmoregulatory stress and must have periodic access to brackish to fresh water [Moler, 1991]. Freshwater needs of the crocodile may often be met in wet years with frequent rainfall which results in a lens of freshwater on the surface that may persist for several days after rainfall. However, hatchlings' dependence on rainfall probably varies as a function of water salinity such that more frequent rainfall is required in high salinity environments [Moler, 1991]. Therefore, hatchling crocodiles are more likely to experience osmoregulatory stress, and resultant reduced growth and survival, in hypersaline areas. Survival rates seem to be inversely correlated with the distance that hatchling crocs have to disperse to find nursery habitat. Lower salinities decrease the dispersal distances of young crocodiles resulting in increased survival. Additionally, adult crocodiles show a strong preference for low salinity areas and water salinity may be locally important in determining habitat use by adult crocodiles, especially during periods of low rainfall [Mazzotti and Brandt, pers. com. 1997; McIvor *et al.*, 1994].

Mazzotti and Brandt [1995] developed a method for determining crocodile habitat suitability based on isohaline data for northeast Florida Bay mangrove habitat. Using this analysis method they predicted that increased freshwater flows to Florida Bay habitat expected to result from the C-111 project would lead to increased habitat area considered most suitable for crocodiles. In an ecological assessment of the effects of the 1994–1995 high water conditions on the crocodile, Mazzotti [in prep] applied the above model with the following results:

1. More fresh water (lower salinity) in northeastern Florida Bay increases the amount and suitability of crocodile habitat;

2. Flows directed through Taylor slough can potentially provide more and better crocodile habitat, and;

3. Under current conditions most suitable crocodile habitat occurs closer to C-111 drainage area than Taylor Slough.

However, no specific hydrodynamic model is currently available to predict salinities and produce an isohaline map for these coastal areas. The USFWS [McSharry, 1998] has recommended substituting as an approximation the correlation of estuarine salinities with upstream water stages at key grid cells in the South Florida Water Management Model. It was proposed that with some adjustment, salinity values defining habitat suitability in the 1995 study can be used to predict changes in crocodile habitat suitability due to changes in freshwater deliveries to Florida Bay (Mazzotti and Brandt, pers. com. 1997). It was recommended by Mazzotti and Brandt that the habitat suitability definitions from the 1995 study be modified for future analysis to better incorporate variability in salinity values that are considered suitable for crocodiles. Recommended definitions are: most suitable habitat, 0-20 ppt; intermediate suitability, 20-40 ppt; and least suitable,> 40 ppt.

1.2.4 Manatee

The Florida manatee (*Trichechus manatus latirostris*), a Federally-listed endangered species, is a fully aquatic herbivorous mammal, a distinction shared only with other Sirenians. The manatee occupies a prominent position in the Park's marine and estuarine systems as a prodigious grazer of submerged aquatic vegetation, spending about five hours a day feeding and in that time consuming about 4 to 9% of its body weight (20-45 kg/day) [Bengtson, 1983]. Submergent aquatic vegetation, such as seagrasses, is a major component of the diet of manatees, and although manatees appear to tolerate marine and hypersaline conditions, they are most frequently found in fresh or brackish waters.

Therefore, the effect of changes in freshwater flow on salinity patterns, submerged vegetation and the overall quality of the foraging habitat in Florida Bay, and elsewhere in the park are, along with water temperature, important influences on the distribution and abundance of manatees in the area. Movements and aggregations of manatees can be correlated to some degree with the distribution of seagrasses and vascular freshwater aquatic vegetation [Hartman, 1974]. Manatees may or may not need freshwater to survive, but they frequently are reported drinking freshwater from hoses, sewage outfalls and culverts in marine and estuarine areas. Little is known about the ability of manatees to osmoregulate and maintain water balance. Recent data suggest that manatees may require regular access to fresh, or perhaps brackish, water to meet water balance needs [Worthy, 1998]. Access to freshwater is probably more important to manatees than currently understood (Lefebvre, pers. com 1998).

Data from aerial surveys conducted from March 1990 through February 1993, show interannual variability in distribution and relative abundance of manatees within northeastern Florida Bay which may be related, in part, to freshwater flow and resultant distribution of food resources. The relative abundance of manatees in northeastern Florida Bay was higher in 1992 compared to the surveys conducted in 1990 following several years of drought [Snow, 1991, 1992, 1993].

Changes in the distribution of manatees in Florida Bay from historic times are, in part, based on anecdotal accounts, but suggest a decline in use of northern Florida Bay. Accounts of manatee distribution and abundance from the 1930s suggest that northern Florida Bay, "including the various streams and estuaries bordering it", was the most important area for manatees in the proposed Everglades National Park [Beard, 1938]. In subsequent years the low number of manatee sightings from Florida Bay in general has been attributed to both the scarcity of fresh water as well as generally shallow conditions [Moore, 1951; Hartman, 1974; Odell, 1979].

A potentially significant departure from the major distribution patterns revealed by Odell [1979] and again by the 1979-1981 surveys of Bass [1982] suggests possible important influences on the distribution of manatees related to freshwater availability and the quantity and quality of available forage. During 1979 through 1981 (a period of locally higher rainfall compared to 1990), significant numbers of manatees were observed in the southern and southeastern Whitewater Bay area [Bass, 1982]. During surveys in 1990, fewer manatees were observed there and in some areas submerged vegetation was scarce to absent [Snow, 1991]. These observations may be due, in part, to changes in available forage (quantity and perhaps quality) and freshwater brought about by natural system variation compounded by effects of water management practices.

Proposed Everglades restoration alternatives which increase freshwater flows into downstream estuaries are likely to have direct effects on the quantity and quality of benthic vegetation available to manatees. What these changes will be, and their magnitude, is not well understood. And how this will affect manatee distribution and abundance is not clearly known. However, it seems reasonable in light of our current knowledge, to assume that more fresh water (lower salinity) in northeastern Florida Bay and the Shark Slough estuaries (Whitewater Bay, etc.) is likely to increase the amount and suitability of manatee habitat. There is general agreement among most manatee biologists that the restoration of more natural water flow volumes, timing and distribution, will be favorable to the continued existence of the Florida manatee (Lefebvre, pers com. 1998). In the absence of a manatee habitat suitability measure for Everglades National Park, or a habitat quality index model, or a spatially explicit individual based model, the same measures used to assess possible effects on crocodiles are used to assess the possible effects of water management alternatives on manatees.

1.2.5 Snail Kite

The Florida population of snail kites (*Rostrhamus sociabilis plumbeus*) is considered to be a single population with considerable distributional shifts [Bennetts and Kitchens, 1997]. The combination of a range restricted to the watersheds of the Everglades, Lakes Okeechobee and Kissimmee, and the upper St. Johns River, with a highly specific diet composed almost entirely of apple snails (*Pomacea paludosa*), makes the snail kite's survival directly dependent on the hydrology and water quality of these watersheds. Snail kites are nomadic in response to water depths, hydroperiod, food availability, nutrient loads, and other habitat changes. Nonbreeding individuals are known to disperse widely on a frequent basis [U.S. Fish and Wildlife Service, 1998a].

According to the U.S. Fish and Wildlife Service [1998a], the snail kite population is now considered more resilient than previously thought to natural climatological fluctuations, but the resilience of snail kites to human-induced changes is less certain. The species is adapted to "boom and bust" cycles, and any consideration of recovery must be based on long-term (at least 10 years) averages in population levels and/or reproductive success. Telemetry indicates that snail kites use a broader network of wetland habitats than was previously recognized. Additional research is needed on survival following periods of drought. Previous opinions regarding the amount of mortality following drought may have been biased by lack of knowledge about the full range of dispersal of the species; mortality may have been overestimated because widely dispersed individuals were living in habitats not regularly searched. The general consensus is that the snail kite population has been at least stable since 1969, and has likely increased, on average, within a broad range of fluctuation [U.S. Fish and Wildlife Service, 1998a].

Water management actions in the Everglades and in the lakes are the most important human-controlled factors in survival and recovery of the snail kite. Bennetts and Kitchens [1997] discussed several aspects of the hydrologic regimes of snail kite habitat, including hydroperiod, intervals between drying events, and the duration of drying events. Snail kites occur primarily in areas with relatively long hydroperiods. It has been suggested that kites require areas of continuous inundation (100% hydroperiod). However, continuous inundation has been well documented to result in a loss of the woody vegetation used by kites for nesting, roosting, and foraging perches. Continuous flooding also may kill sawgrass and other graminoid species that are an essential component of kite foraging habitat. Observable changes in plant communities in the absence of drying have occurred after 5-6 years [Comiskey *et al.*, 1998]. Nesting kites use wetlands having long term inundation lengths ranging from about 80% to 99% of the time. Foraging kites during non-breeding often use habitats inundated as low as 70% of the time [Bennetts and Kitchens, 1997]. For the snail kite we must recognize the importance of a heterogeneous landscape within wetlands of relatively long (>85%) average hydroperiod. We must also acknowledge that these areas will, and should, dry out periodically.

In evaluating the effects of these drying events on the demography of the snail kite, we must consider the average interval between drying events, their duration, and spatial extent. Localized drying events are thought to have little adverse effect on the snail kite population, but droughts across the region extending from the St. Johns marsh and the Kissimmee Chain of Lakes to the southern Everglades are likely to have adverse effects. During the period of 1969 - 1994 the average interval between droughts for WCA-3A and Lake Okeechobee, two areas most frequently used by kites during this time period, was 3.6 and 3.8 years respectively and the kite population has been increasing [Bennetts and Kitchens, 1997]. Some authors have emphasized the importance of the availability of suitable habitat during periods of drought, which were thought to be a limiting factor in the population [U.S. Fish and Wildlife Service, 1998a]. Bennetts and Kitchens [1997] believe that snail kites spread the risk of fluctuating habitat conditions by their ability to move long distances across the landscape within a "network" of habitats. They hypothesize that the spatial extent and heterogeneity of habitat quality throughout the snail kite's range buffers the risks that may be posed by droughts, because the spatial extent and duration of drought conditions will vary across the species' range. Because the 1992–1995 duration of Bennetts' study did not include a period of drought, continued radio-tracking of snail kites during a drought will be necessary to confirm this hypothesis.

The duration of a given drying event may affect the survival of apple snails. Darby *et al.* [1997] found that the average survival of apple snails experiencing a drying event was 3.9 weeks. Droughts of greater duration may have more of an impact on apple snail populations than those of short duration. Evidence suggests that apple snail populations may take more than 1 year to recover to pre-drought levels. Darby *et al.* [1997] have indicated that the timing of a drying event may be a critical factor in how it affects the apple snail population. Snails hatched during the previous year undergo an almost complete die-off during May-July following reproduction. Thus the cohort that provides the breeding potential for the next year are those that hatched in the preceding year. Given that the peak of snail egg laying occurs from March-May, a drying event that occurs before May can deplete the cohort of breeders for the following year, requiring at least an additional year for the recovery of snail populations to pre-drought levels [Comiskey *et al.*, 1998].

1.3 Base Hydrologic Condition

Detailed modeling efforts in support of this effort commenced on May 4, 1998. At that time, we collected the best available information and tools necessary for the hydrologic analyses. These consisted of

1. The South Florida Water Management Model (SFWMM) version 3.4.

   The hydrologic analysis in this report is based on simulations performed with the South Florida Water Management Model [MacVicar *et al.*, 1984; South Florida Water Management District, 1997]. During the Restudy, the Hydrologic Systems Modeling Division of the South Florida Water Management District provided the Everglades National Park on January 5, 1998, with the all of the source code and input files for the SFWMM version 3.4. Also included were the Restudy 1995 Base, the Restudy 2050 Base, and Alternatives 0–3.

2. The Natural System Model.

   The Hydrologic Systems Modeling Division also provided output from the Natural System Model [Fennema *et al.*, 1994] on April 27, 1998. File names indicate that it was version 4.5.

3. Other information

   For canal operations, Table 2 shows most of the relevant structure operations used in this simulation. The 1983 Base condition was developed from the information provided by the Hydrologic Systems Division of the SFWMD in the following manner. First, the 1995 land use and wellfield pumpages used in the Restudy were included in the 1983 Base. Second, operational rules as defined in the "Operational Criteria" document were incorporated into the model input where appropriate. The 1983 Base was defined use the most recent Environmental Assessment U.S. Army Corps of Engineers [1997a]. The structure G-211 was completely removed from the input files, and L-31N canal and levee were reconfigured to reflect this change. Lastly, minor code modifications were made to allow the simulations to run on ENP computers; these had no effect on the calculations.

The volume of output from a model as complex as the SFWMM makes editing, selective presentation and expert interpretation absolutely essential. For example, since the reconsultation is related to Experimental Water Deliveries, Modified Water Deliveries and the

C-111 Project, we will limit our examination of results to Water Conservation Area 3A, Water Conservation Area 3B, and Everglades National Park. This allows more more analysis of the effects in the areas primarily affected by the projects. In this report, we will focus on presenting and interpreting model results in a general way, and provide more detailed performance measure comparisons between individual modeling scenarios.

Figure 3 is an example of a general model result. Shown is a water budget for WCA-3A, WCA-3B, and Everglades National Park. The average annual result is useful for determining average structure flows, groundwater seepage, and relative magnitudes of each component. In the 1983 Base condition, the SFWMM estimates 930,000 acre-ft per year into Shark Slough, all through the S-12 structures. Seepage out along L-31N averaged 115,000 acre-ft per year. Rainfall and evapotranspiration dominate the water budget; rainfall accounted for 70% of the inflow to Everglades National Park, while evapotranspiration was 60% of the total outflow.

As the primary purpose of the 1983 Base condition is as a comparative basis for all simulations, more detailed information about the 1983 Base is presented along with the analysis for individual simulations.

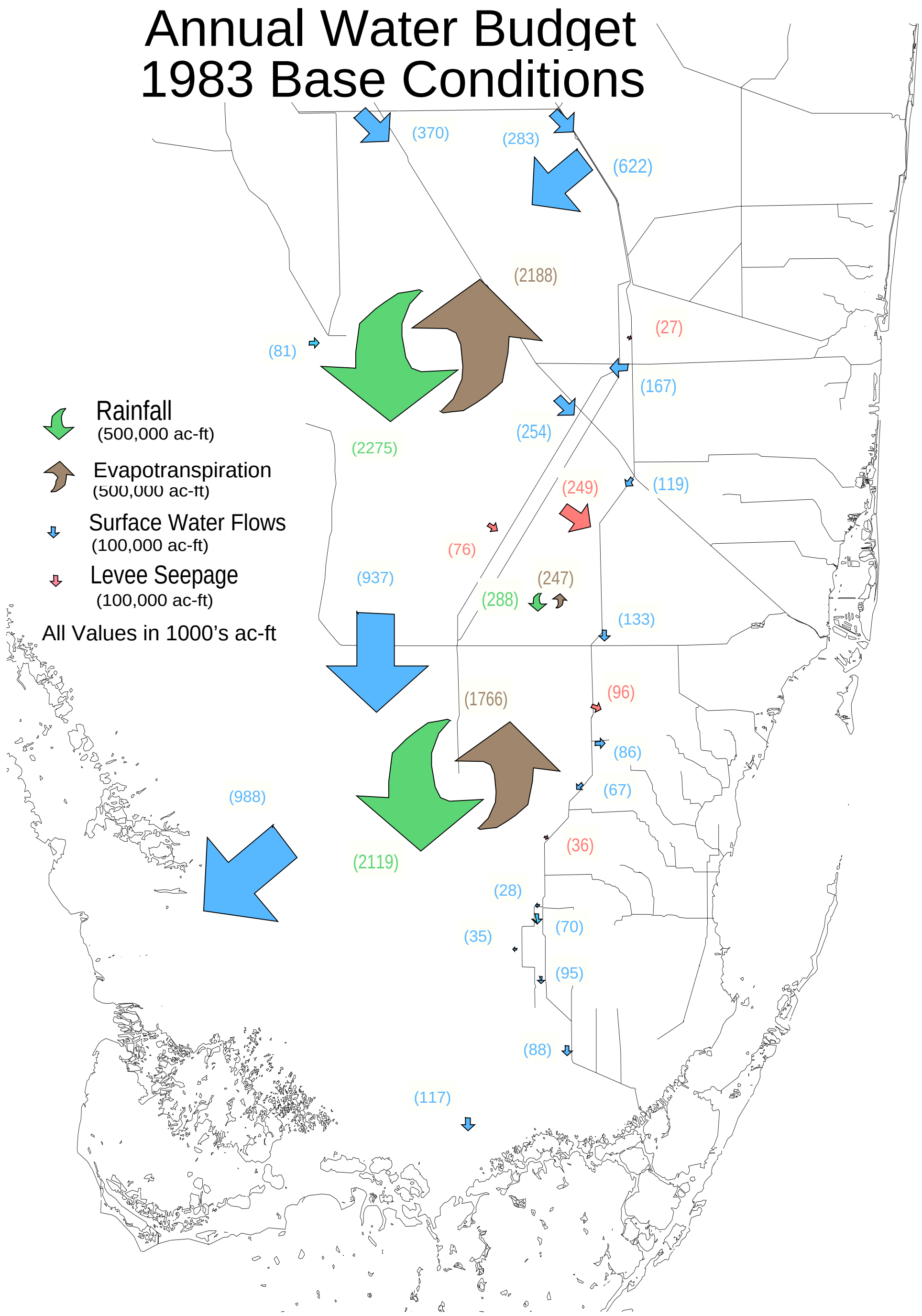


Figure 3: Average annual water budget for the 1983 Base Condition.

Chapter 2

Experimental Water Deliveries Project

2.1 Background

Public Law (PL) 98-181, inacted in November 1983, authorized the Corps of Engineers, with the concurrence of the South Florida Water Management District and the National Park Service to implement the Experimental Water Deliveries Program (EWD). Congress authorized the Corps, in concurrence with the SFWMD and the NPS, to experiment with the delivery of water to Everglades National Park in order to provide ecosystem benefits and reverse the ecological decline in the Park. Furthermore, the Law authorized the Secretary of the Army to construct the necessary measures to provide flood protection for homes in order to meet the goals of the program. The Law also authorized the Secretary to acquire agricultural lands threatening the realization of these objectives [U.S. Army Corps of Engineers, 1992]. The program was re-authorized every two years until 1989 when permanent authority was issued pending the completion of permanent structural modifications approved under the Everglades Expansion Act of 1989. This legislation provided the Army Corps of Engineers with the authority to use the EWD as an iterative field testing program for developing optimum water delivery plans for ENP.

Factors leading to the Experimental Water Deliveries Program

Prior to the enactment of PL 98-181, the ecological impacts associated with inadequate fixed monthly water delivery volumes and large regulatory flood releases to ENP concentrated solely into western Shark Slough were becoming more frequent and the associated ecological damage better documented. These surface waters inflows to western Shark Slough were out of sync with the natural timing of rainfall and at the spatial extent of the historic Shark Slough flowway. In 1982 the Army Corps of Engineers [U.S. Army Corps of Engineers, 1982] completed a draft Feasibility Study and draft Environmental Impact Statement (EIS) for the Shark Slough watershed. This document concluded that restoring surface water deliveries to Northeast Shark Slough (NESS) would improve the hydrologic conditions in both NESS and downstream marshes. Additionally, this action would mitigate the extreme high water conditions occurring in western Shark Slough due to the large S-12 regulatory discharges.

Record rainfall combined with sustained dry season S-12 regulatory releases in late 1982 through early 1983 again produced hydrologic conditions resulting in ecologic damage in the western Shark Slough basin. In March of 1983, a 7-point plan was presented by ENP to the SFWMD Governing Board requesting immediate relief from and prevention of future S-12 flood discharges [Hendrix, 1983]. The plan provided a general outline of steps required for successfully eliminating the environmentally undesirable effects of water management activities in the Shark Slough basin. The plan included implementation of both operational and structural modifications to the existing Central and Southern Flood Project. The plan emphasized the following elements:

- Re-establishment of flows along the entire historic Shark Slough cross-sectional flowway, including Northeast Shark Slough. This includes the re-introduction of surface water flows into Water Conservation Area 3-B and flow through to Northeast Shark Slough.
- Removal or modification of as many of the man-made features such as levees acting as barriers and water control structures that impede the natural surface water flows within the historic Shark Slough and Big Cypress National Preserve basins.
- Implementation of a water delivery plan for the Shark Slough flowway synchronized with the natural timing of rainfall.

In response to this request for relief, the SFWMD and the Army Corps of Engineers approved the temporary use of S-333 to mitigate for the severe high water problems in western Shark

Slough. Structure S-333 opened in late March 1983 and remained open until mid-June 1983 when it was closed due to concerns over the potential of increased flooding in the East Everglades. Despite the closure of S-333 during the wet season of 1983, flood control operations were initiated in June 1983 at the newly constructed water supply pump S-331. Although the use of S-331 for this purpose was not part of its original authorization, flood operations were implemented due to the potential of lawsuits initiated by landowners of the East Everglades and other south Dade areas.

In June 1983, Corps, the District and the Park agreed to establish a two-year field test to improve water deliveries to western Shark Slough. As originally conceived the implementation of the Flow-Through Plan would allow surface water to flow freely, uncontrolled and unregulated from WCA-3A to western Shark Slough through the S-12 structures. During this period many of the other 7-point plan elements were altered and implemented, including the installation of plugs in L-67 extension canal and construction of two new water control structures in L-28. Although the House and Senate resolutions clearly stated that "the investigation shall include, but not be limited to, consideration of structural and other appropriate measures to improve the future environmental conditions of the Park with special regard to providing adequate supply and distribution of water with acceptable quality to the Everglades National Park" the elements offered in the 7-point plan were considered to infringe upon the other C&SF Project objectives. The consensus was that the resolution objectives could be achieved without significant modification to the project as proposed by the 7-point plan.

The Flow-Through Plan yielded several findings about the hydrologic conditions in the Shark Slough basin. Environmentally, although producing high sustained inflows into western Shark Slough the removal of the large slugs of water associated with S-12 regulatory releases resulted in more natural dry season recessions within the Shark Slough wetlands [Everglades National Park, 1995]. Unfortunately, the water supply aspects of the project where negatively impacted with the uncontrolled flows depleting the available WCA-3A storage. By May 1985, following a period of below normal dry season rainfall, the Flow-Through test ended prematurely.

Following the completion of the Corps Environmental Assessment (EA) and issuance of a Finding of No Significant Impact (FONSI) in January 1984 for the reintroduction of surface water flows to NESS via S-333 a series of field test were initiated. The FONSI was very explicit concerning the proposed plans potential impacts stating, "flooding impacts [in the East Everglades] resulting from the proposed plan, however, appear to be inconsequential".

Nevertheless, East Everglades water levels were used as a constraint to limit the operation of S-333 and inflows to NESS.

Implemented concurrently to the the Flow-Through experiment the 30 and 90 day field tests, in April–May 1984 and August–November 1984 respectively, were initiated with the goal to optimize surface water deliveries to Northeast Shark Slough while preserving other project objectives of flood protection and water supply. Agricultural interests and residents in the areas adjacent to NESS were very concerned about the potential of adverse impacts to their level of flood protection during the tests. To belay their concerns each of the tests were conducted under negotiated agreements between the District, agricultural interests and residents in the areas [MacVicar, 1985]. These agreements outlined the conditions for S-333 inflows that would assure agricultural and residents not be negatively impacted. The results of these shorter duration tests provided insights into both the environmental and flood protection aspects of introducing inflows into NESS. Analysis of data collected during the 30- and 90- day tests indicated that large discharges to NESS through S-333 were possible without adversely increase risk of flooding in the adjacent areas [MacVicar and VanLent, 1984; MacVicar, 1985]. Additionally, analysis from field test data failed to show a clear linkage between S-333 inflows and water levels in the East Everglades.

Test Iteration 1 through 5 of the EWD Program

The first official field test of the EWD, Test 1 to be conducted began in July 1985, following the completion of the EA [U.S. Army Corps of Engineers, 1985], and continued for 2 years. The principal component of this test was the implementation of a rainfall plan in determining surface water deliveries to Shark Slough. Additionally, the fixed regulation schedule in Water Conservation Area 3A was replaced with a set of five operation zones. The formula for water deliveries were made as described by T. MacVicar in Appendix A.1 of Neidrauer and Cooper [1989]. Water level criteria for S-333 inflows to NESS were also modified to provide more flexibility to the experiment. This modification was necessary because constraints on S-333 inflows, as imposed in the shorter duration tests prevented determination of whether restoration objectives for NESS flows and consequently Shark Slough were being met [Neidrauer and Cooper, 1989].

The results of this first test raised additional concerns about the ability of the EWD program in meeting the stated objectives. Through both wet seasons of the field tests the regulatory component often exceeded the rain driven component by a factor of two [Neidrauer and Cooper, 1989]. Because of the L-29 and G-3273 constraints to S-333 operation, its utilization was significantly reduced. These factors lead to a continuation of the large regulatory discharges to western Shark Slough and the inability to reintroduce wet season surface water flows to Northeast Shark Slough.

Neidrauer and Cooper [1989] also found that the G-3273 constraints imposed to limit S-333 inflows were not always necessary. Limited S333 inflows combined with lowered L-31N canal stages overcompensated for impacts caused by the NESS portion of the experimental program, and produced water levels in many parts of the East Everglades that were lower than those prior to the initiation of the test [Neidrauer and Cooper, 1989; Van Lent *et al.*, 1993].

Tests 2 through 5 extended the experimental testing program with no significant changes. The test number was incremented to indicate Congressional reauthorization and continuation of the Experimental Water Deliveries Program.

Test Iteration 6 of the EWD Program

Test 6 of the experimental program began in July 1993 and authorized to continue through June 1995 [U.S. Army Corps of Engineers, 1993]. Analyzes of the hydrologic data from test iterations 1 through 5 indicated that over-drainage of NESS, Rocky Glades and Northern Taylor Slough wetlands was resulting from the reduction in operational criteria associated with these test. Therefore, the primary focus of Test 6 was on the re-evaluation of the operating criteria for structures throughout the L-31N, L-31W, and C-111 canals [Everglades National Park, 1995]. During Test 6, water deliveries into Northeast Shark Slough continued, following the previous testing criteria. The objectives of the EWD program were expanded by the Corps [U.S. Army Corps of Engineers, 1993] to: "evaluate methods to restore a more natural hydroperiod to ecosystems within ENP including NESS and Taylor Slough, as well as, reduce large, freshwater discharges through S-197 into Manatee Bay and Barnes Sound." Test 6 also became known as the *Taylor Slough Demonstration Project*.

Prior to Test 6 water levels in the canals adjacent to Taylor Slough wetlands and the Frog Pond agricultural area were lowered to allow land preparation and planting to begin in mid-October [Johnson *et al.*, 1988; Van Lent *et al.*, 1993]. The lowering of these canals resulted in an artificial drawdown of the water table not only in the Frog Pond but in ENP wetlands. The first occurrence of this artificial lowering of the water table was agreed to by ENP in 1984 as a one-year experiment for evaluating the effects of L-31W drawdowns on the water resources of Taylor Slough. The findings of this first experiment resulted in a recommendation that future drawdowns not take place [Wagner *et al.*, 1985]. Without concurrence of ENP, the experiment continued for the next three years under agreement between the SFWMD and south Dade farmers related to the Northeast Shark Slough elements of the Experimental Water Deliveries Program. A technical report documenting the hydrologic impacts to the ENP resources of Taylor Slough resulting from the 3 previous years of drawdowns [Johnson *et al.*, 1988] prompted the Corps to inform the District that they could no longer approve of continuation of the drawdowns. October drawdowns continued until the start of Test 6 when modified to delaying the drawdown till later in November and and increase in the dry season L-31W operating criteria.

ENP's stated primary goal during the planning process for the June 1993 EA was maintaining optimum wet season water levels in the L-31N, L-31W, and C-111 canals for as long as possible, and allowing for a natural recession from the wet to the dry season. ENP further stated that it is not the goal to move the maximum amount of water to the west (into Taylor Slough), when the source of the majority of these flows is from excessive drainage of the upstream wetlands in NESS and the Rocky Glades [Everglades National Park, 1995]. ENP's focus on maintaining higher water levels in the L-31N, L-31W, and C-111 canals would allow more of the wet season rainfall to be stored in the upstream wetlands and underlying aquifer. This approach would reduce excessive groundwater seepage losses, attenuate the rapid flow pulses associated with flood control operations, and delay the release of wet season runoff, producing more persistent flows into the dry season [Everglades National Park, 1995]. These concerns resulted in increased water deliveries to the Taylor Slough basin. The Taylor Slough iteration was added to test whether increased pumping of up to 500 cfs at the S-332 pump station would increase flows through Taylor Slough, thereby rehydrating the adjacent wetlands and providing for additional freshwater inflows to Florida Bay.

Findings of the data collected during the first year of Test 6 were presented in a technical report by ENP [Everglades National Park, 1995]. Record rainfall produced large regulatory discharges limited to western Shark Slough due to restrictions placed on surface water deliveries to Northeast Shark Slough. The existing gradients between the higher water levels in ENP wetlands and the L-31N canal system with lowered of operational stages continued to result in large ground-water losses from ENP to the east. The delay of the artificial drawdown from October to November did produce some benefit of sustaining wet season water levels later into the dry season [Everglades National Park, 1995], but in the eventual drawdown, the impacts to Taylor Slough were apparent.

2.2 Description and Simulation of Test 7

2.2.1 Description

The complete description of Test Iteration 7 of the Experimental Program of Water Deliveries to Everglades National Park is found in the environmental assessment (EA) completed by the Corps of Engineers [U.S. Army Corps of Engineers, 1997a] and other related documents. This iteration continued to focus on the findings of earlier iteration regarding the importance of the rehydration of the Rocky Glades and Taylor Slough within the boundaries of Everglades National Park (see Fig. 1) [U.S. Army Corps of Engineers, 1997a]. To achieve these objectives for the Rocky Glades wetlands operational stages in L-31N were increased, but remain below the authorized levels. In the Taylor Slough basin a rainfall plan was implemented in combination with the removal of the November drawdown and a single maximum year-round operational criteria.

Test 7 included implementation of both modification of operational criteria and addition of structural components. The increase in canal operating stages above G-211 in L-31N, in L-31N above S-176 and initiation of a rainfall formula in for determining L-31W operational stages could be readily implemented. The structural components required in Test 7 included an auxiliary pump to be located at S-173 and the larger 500 cfs pump station to be constructed adjacent to S-174. Implementation of a configuration of smaller auxiliary pumps would provide greater flexibility to management of water levels in East Everglades. To meet the stages predicted by the rainfall formula for L-31W using the available historical rainfall record, a larger pump station (S-332D) for water deliveries to Taylor Slough was also scheduled for construction. Because S-332D was not constructed at the time that Test 7 was slated to begin, the iteration was broken into two phases. Phase I was a partial implementation, with slightly lower L-31N canal stages below C-1W and limits on the maximum and minimum stages allowed in the L-31W canal. Phase II was scheduled to be begin as soon as S-332D was constructed allowing for stages in L-31N and L-31W to be increased as noted.

The operational stages for structures of the South Dade Conveyance System and C&SF Project structures are shown in Table 2. The criteria shown are those simulated in the

Canal Name	Structure Name	1983 Base		Test 7 Phase I		Test 7 Phase II	
		Open	Close	Open	Close	Open	Close
L-31N	S-338	5.2	4.8	5.8	5.5	5.8	5.5
L-31N	G-211	Not constructed		6.0	5.5	6.0	5.5
L-31N	S-331	TW $<$ 4.0	TW $>$ 6.0 or HW $<$ 3.0 or S176HW $>$ 4.7	Angel's Well[a] Criteria		Angel's Well Criteria	
L-31N	S-194	5.7	5.3(5.2)	5.7	5.3(5.2)	5.7	5.3(5.2)
L-31N	S-196	5.7	5.3	5.7	5.3(5.2)	5.7	5.3(5.2)
L-31N	S-174	5.5	5.1	4.85	4.65	See S-332D	
L-31N	S-176	5.7	5.3	5.0	4.75(4.6)	5.2	5.0(4.85)
L-31N	S-332D	not constructed		not constructed		5.0 RDP for L-31W No max TW stage	4.80
WCA-3A	S-332	Minimum Deliveries		Rain Driven Max WCA-3A stage		Not Used	
WCA-3A	S-175	4.7	4.3	4.7	4.3	Not Used	
C-111	S-177	5.2	4.3	4.2	3.6	4.2	3.6
C-111	S-18C	2.4	1.6	2.6	2.3	2.6	2.3
C-111	S-197	S-197[b] Criteria		S-197[c] Criteria		S-197[d] Criteria	
C-1W	S-148	5.7	3.7	5.0	4.0	5.0	4.0
C-102	S-165	5.9	5.1	4.0	3.3	4.0	3.3
C-103	S-167	5.9	5.1	4.0	3.3	4.0	3.3
C-103	S-179	5.9	5.1	4.0	3.3	4.0	3.3

[a] If 5.5 <Angel's well < 6.0, pump to maintain S-331 HW between 4.5 & 5.0; If Angel's well > 6.0 pump to maintain S-331 HW between 4.0 & 4.5, until Angel's <5.7;Terminate pumping if S176 HW > 5.5;Terminate pumping if S-331 TW > 6.0; Resume pumping when S176 falls below 5.0

[b] If S-177&S-18C Open Full &S-177HW > 4.3

[c] If S-177& Either S-177HW >4.1 or S-18C > 2.8 Open 3 Culverts;If S-177HW >4.2 or S-18C > 3.1 Open 7 Culverts;If S-177HW >4.3 or S-18C > 3.3 Open 13 Culverts

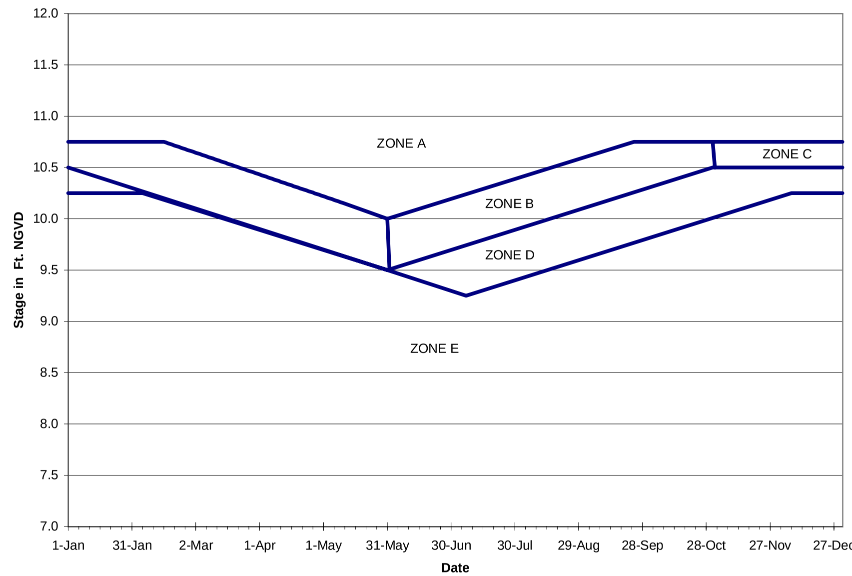
[d] If S-177& Either S-177HW >4.1 or S-18C > 2.8 Open 3 Culverts;If S-177HW >4.2 or S-18C > 3.1 Open 7 Culverts;If S-177HW >4.3 or S-18C > 3.3 Open 13 Culverts

Table 2: Summary of Test 7 Operations for the southern components of the South Dade Conveyance System.

modeling. Operational rules for the water conservation areas and Shark Slough surface water deliveries to ENP for each of each simulation are shown in Table 3. The rainfall plan consists of two components; the base flow and regulatory release components. The base flow, which deviates weekly in response to rainfall over WCA 3A, is calculated by the Rainfall Formula [Neidrauer and Cooper, 1989, p.A1]. The regulatory flood release component is added to the base flow as WCA 3A average stages incrementally increases above the regulation schedule. The Water Conservation Area 3A schedule that determines the flood releases is shown in Figure 4.

2.2.2 Analysis

A reasonable place to begin the hydrologic analysis for the Experimental Water Deliveries is the water budget. Figures 5–6 are the average annual water budgets estimated by the



ZONE	Description	S-12's	S-333
A	Flood Releases	S-12 A - D open full	max. allowable discharge
B	Upper Transition, Wet Season	S-333 Open: Discharge 45% of computed flow S-333 Closed: Discharge At Least 73% of computed flow up to 100% if desired by ENP	discharge up to 55% of computed flow when permitted by this agreement
C	Upper Transition, Dry Season	S-333 Open: Discharge 45% of computed flow S-333 Closed: Discharge 45% of computed flow Plus all or part of S-333's amount if desired by ENP	Same as Zone B
D	Lower Transition, Dry Season	S-333 Open: Discharge 45% of computed flow S-333 Closed: Discharge 45% of computed flow Plus all or part of S-333's amount if desired by ENP	Same as Zone B
E	Rainfall Formula Only	Discharge 45% of computed flow whether S-333 is open or closed	Same as Zone B

Figure 4: Water Conservation Area 3A Regulation Schedule.

Canal Name	Structure Name	1983 Base Operation	Test 7 Phase I Operation	Test 7 Phase II Operation
L-29	S-333	Water supply[a]	Rainfall Formula Close when TW > 7.5 Close when G-3273 > 6.8	Rainfall Formula Close when TW > 7.5 Close when G-3273 > 6.8
L-29	S-334	Water Supply[b]	Closed	Closed
L-29	S-12	Minimum Deliveries Flood Releases	Rainfall Formula [c] Flood Releases (see Fig 4)	Rainfall Formula Flood Releases (see Fig 4)
L-28	S-343A&B	Not constructed	Flood Release (see Fig 4)	Flood Release (see Fig 4)
L-28	S-344	Not constructed	Flood Releases (see Fig 4)	Flood Release (see Fig 4)

[a] In the simulations, S-333 was not used for water supply. Comments by C. Neidrauer during the review suggested a SFWMM v3.4 coding fault which precluded the proper S333/S334 tadem operation.

[b] See above note.

[c] The rainfall formula is described in Appendix A of Neidrauer and Cooper [1989]

Table 3: Summary of Test 7 Operations for Water Conservation Area 3A and the northern components of the South Dade Conveyance System.

SFWMM for Test 7 Phases I and II, respectively.

In Shark Slough, both Test 7 Phase I and Phase II look nearly identical. This is to be expected, as both scenarios have the same operational rules for S-333 and S-12. The SFWMM estimates Test 7 Phases I and II flows of approximately 150,000 acre-ft of flow through S-333 into Northeast Shark Slough. This corresponds to approximately 85% of the flow into western Shark Slough, and 15% into Northeast Shark Slough. Relative to the 1983 Base condition, one can note several changes. First, average seepage along L-31N increase substantially, while evapotranspiration is increased slightly. Average flows into Everglades National Park along Tamiami Trail decrease slightly (7%), while average net flows towards the Shark Slough estuaries decreases markedly more (13%.)

The largest differences between Test 7 Phases I and II are seen in the L-31N/C-111 basin and L-31W/Taylor Slough. Structure S-331 shows the increase in flow volume resulting from an operational shift from strictly water supply to water supply/flood control. Under the 1983 Base, S-331 is operated only for water supply to the South Dade Conveyance System (SDCS). Under Experimental Water Deliveries, it has been operated to provide flood protection to the basin between S-331 and G-211. The pumped volume increases from about 70,000 to 180,000 acre-ft per year. To compare, this differences is about $\frac{3}{4}$ of the amount introduced at S-333, and approximately 2 times larger than the additional seepage under L-31N.

The L31-W basin shows significant changes between the 1983 Base, Test 7 Phase I, and Test 7 Phase II. The 1983 Base shows very little inflow into L31-W; the net surface water

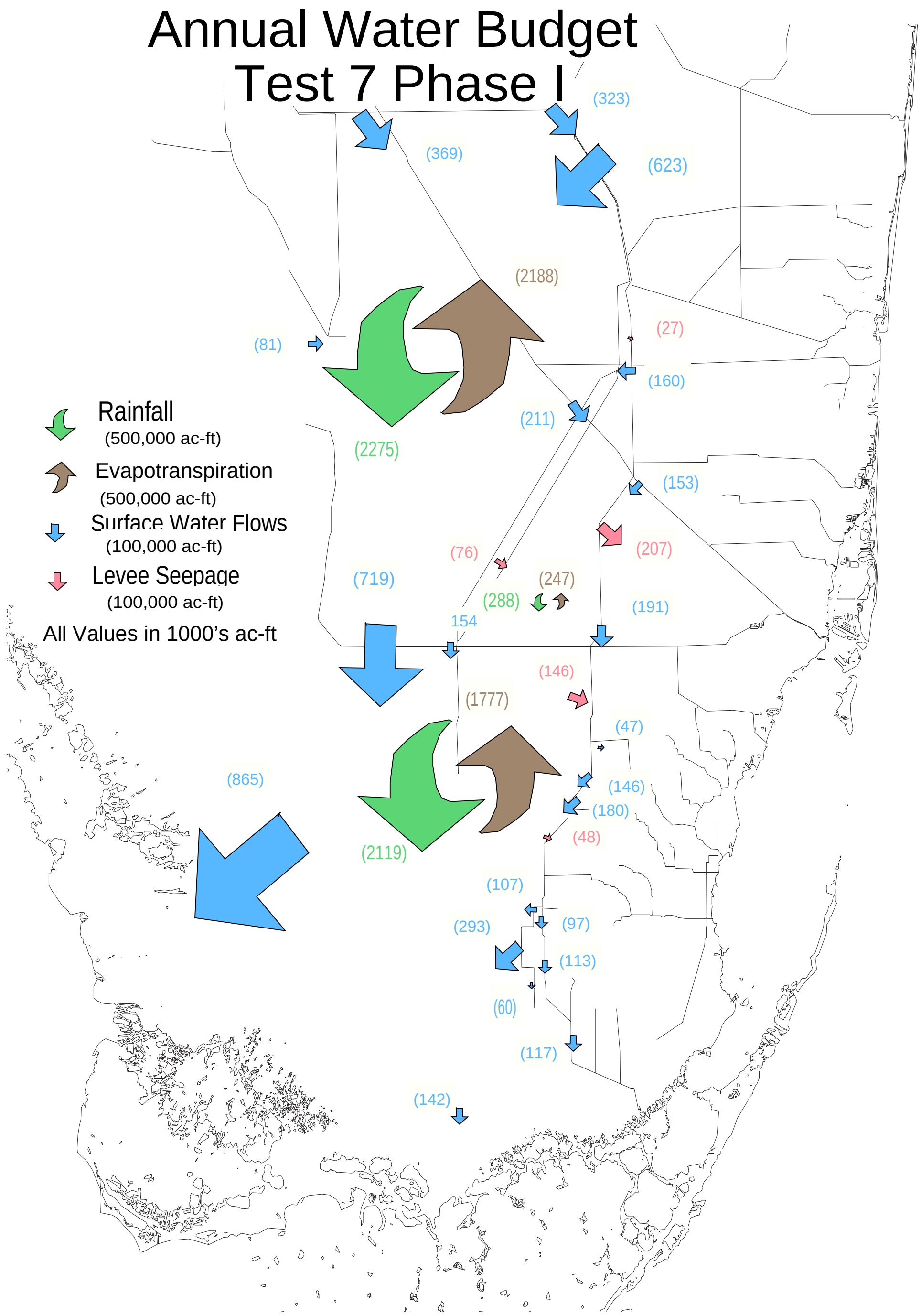


Figure 5: Average annual water budget for the Experimental Water Deliveries Test 7 Phase I.

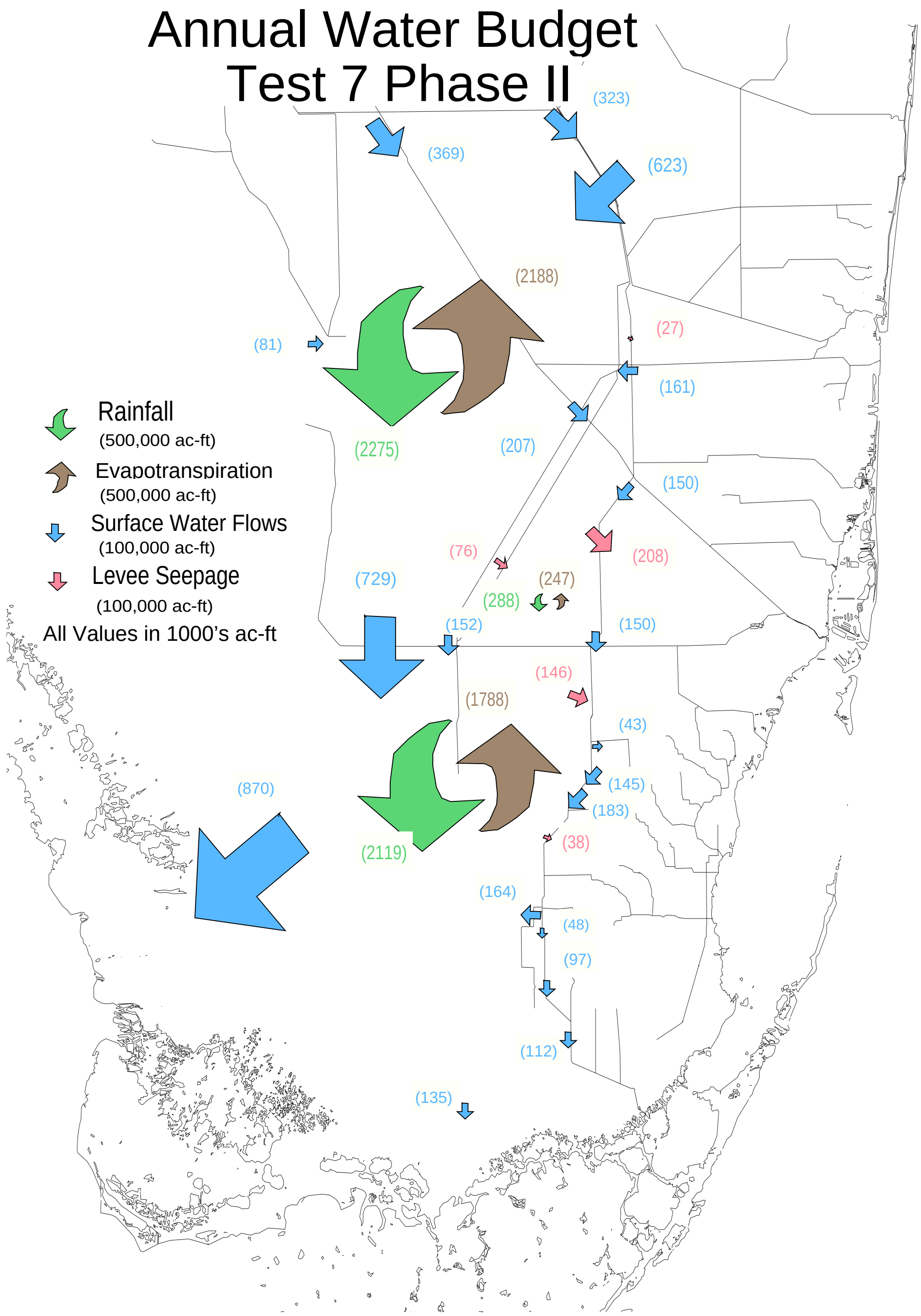


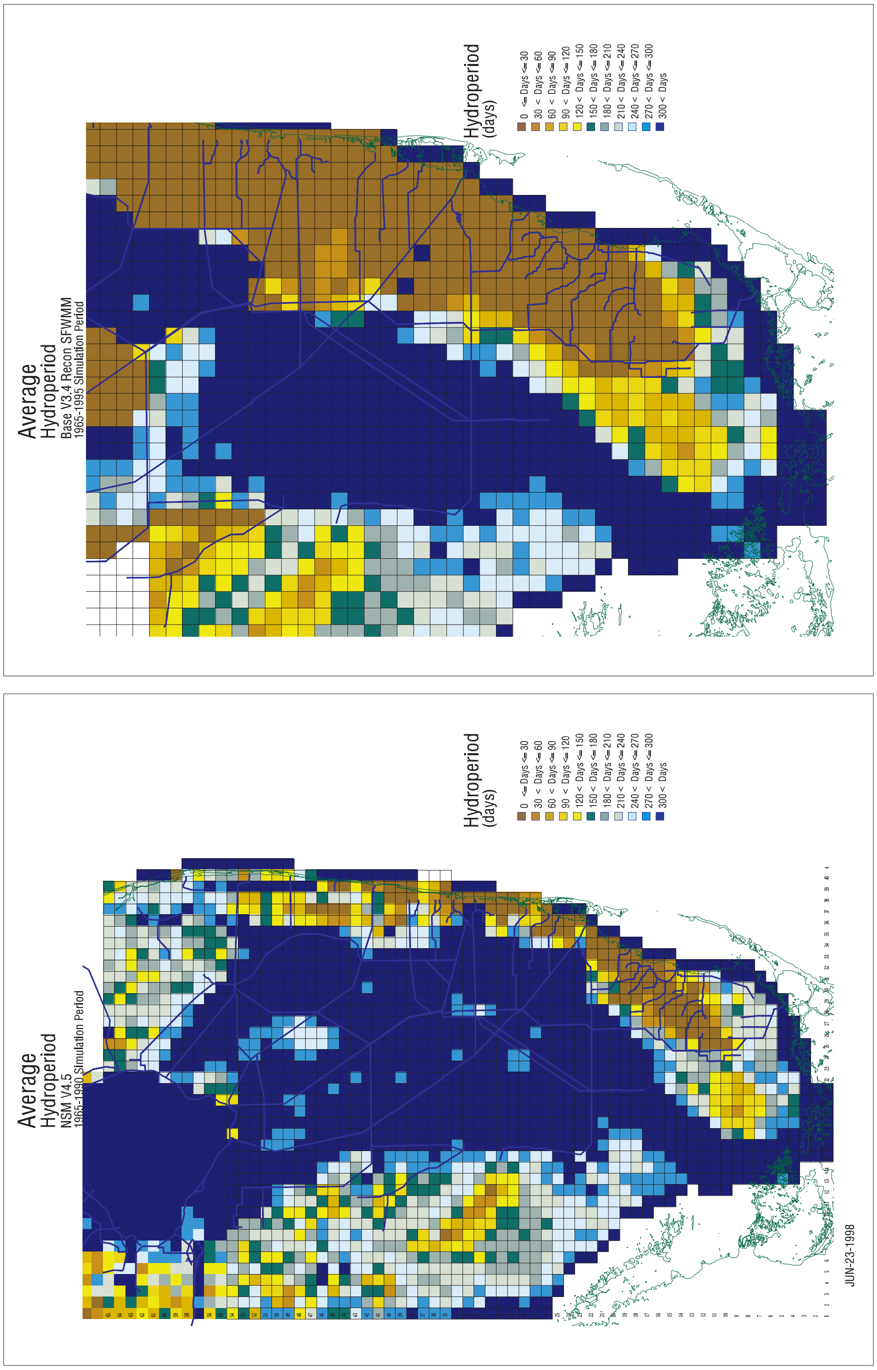
Figure 6: Average annual water budget for the Experimental Water Deliveries Test 7 Phase II.

inflow (S174 less S175) is roughly 30,00 acre-ft per year. Test 7 Phase I increases this to 50,500 acre-ft per year, but pumps 295,000 acre-ft per year at S-332. The large S-332 flows result from S-332 attempts to pump down to the Phase I stage targets for Taylor Slough. Test 7 Phase II shows a surface water contribution of 174,000 acre-ft at S-332D, and an increase in flows towards Florida Bay, relative to the Base. This improved hydrologic response was the main objective and primary benefit of Test 7 Phase II relative to Test 7 Phase I.

In addition to the water budgets, hydropattern difference maps also provide a global view of the difference between operational plans. Figures 7–10 compare hydroperiods and hydroperiods differences for Test Iteration 7 Phase I and Phase II of the Experimental Water Deliveries Program, as well as a comparison between NSM and the 1983 Base, for comparative purposes. The hydroperiod difference maps indicate that Test 7 Phase I has shorted hydroperiods (drier) in western Shark Slough, but longer hydroperiods (wetter) in Northeast Shark Slough. Moreover, Test 7 Phase I relative to the Base shows longer hydroperiods immediately south of S-332, but shorter hydroperiods north of S-332 and in the Rocky Glades. Test 7 Phase II remedies this situation, as it was designed to do.

Another reasonable indicator of average hydrologic behavior is water level. Figure 11 shows the expected change in average annual maximum stage for Test 7 Phases I and II relative to the 1983 Base. The stage differences show small decreases in the average annual maximum stages in western Shark Slough. This is consistent with the decrease in hydroperiods and flows through the S-12 structures. Similarly, one sees increases in Northeast Shark Slough, which is consistent with increases in surface water inflows through S-333. Water Conservation Areas 3A and 3B also seen increased stages, but probably for different reasons. WCA-3A has small increases in stages because of the lower annual flows into Everglades National Park. WCA-3B has increased stages primarily because of decreased seepage out of WCA-3B into Northeast Shark Slough and increased seepage into WCA-3B from WCA-3A. The developed areas of Miami-Dade county experience substantial decreases in average annual maximum stage. These lower water levels result from the lower canal stages for nearly every canal in south Dade, relative to the 1983 Base condition (see Table 2.)

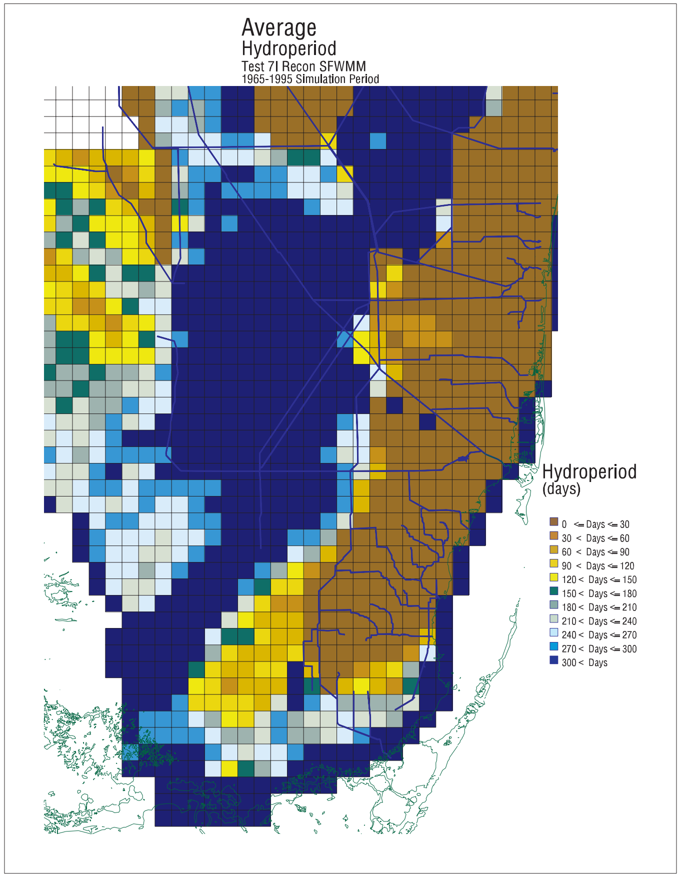
Although average annual results give a general idea, they are not a complete insight into the hydrologic response. For example, in assessing western Shark Slough, one could look at the return frequencies of hydroperiods, annual maximum ponding, and annual minimum ponding to get an idea of what happens under a range of rainfall conditions. Figures 12 –14



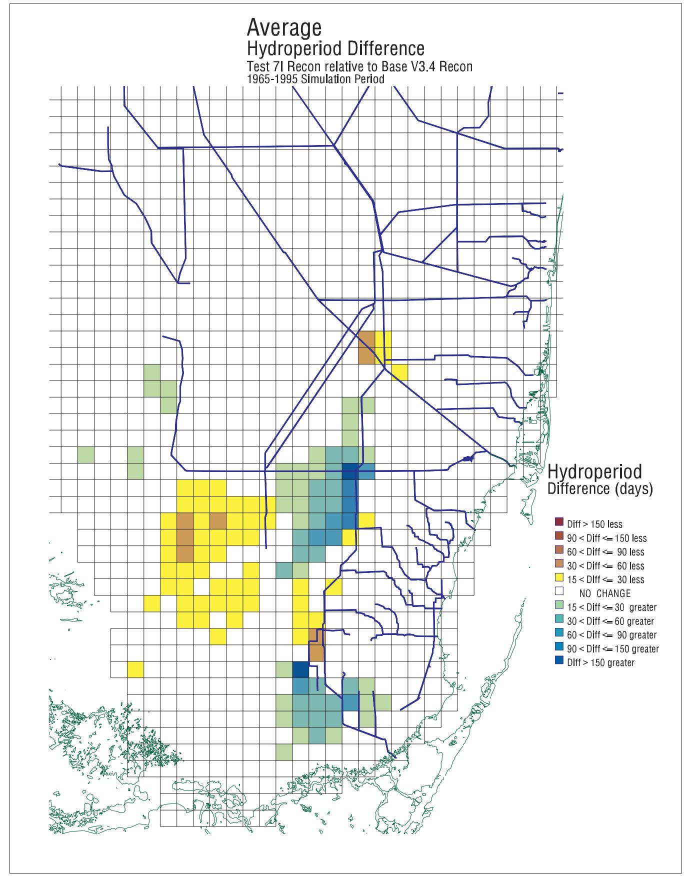
(a) NSM

(b) 1983 Base

Figure 7: Comparison of average annual hydroperiods between the NSM and 1983 Base Condition.

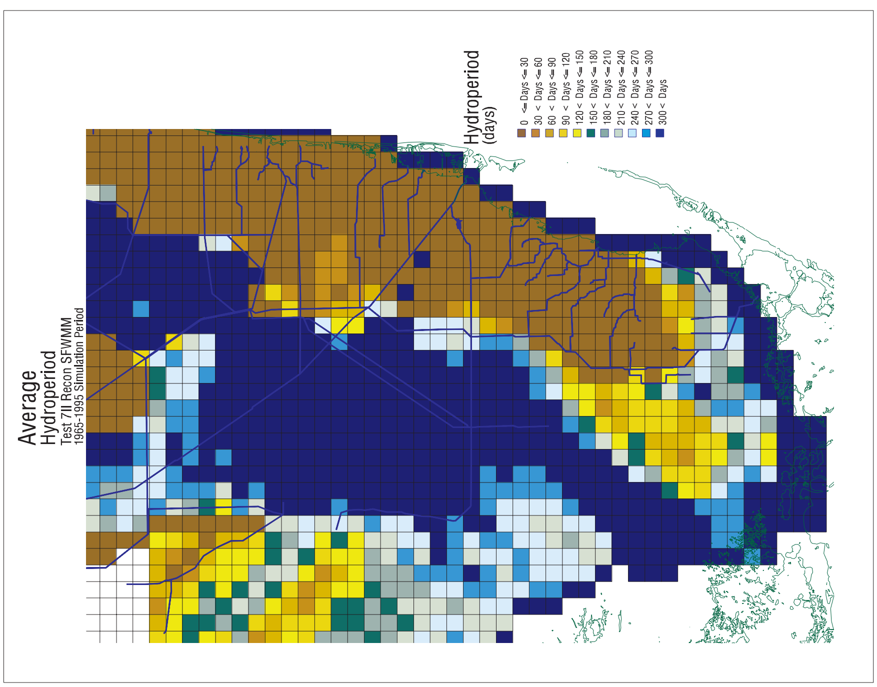


(a) Test 7 Phase I

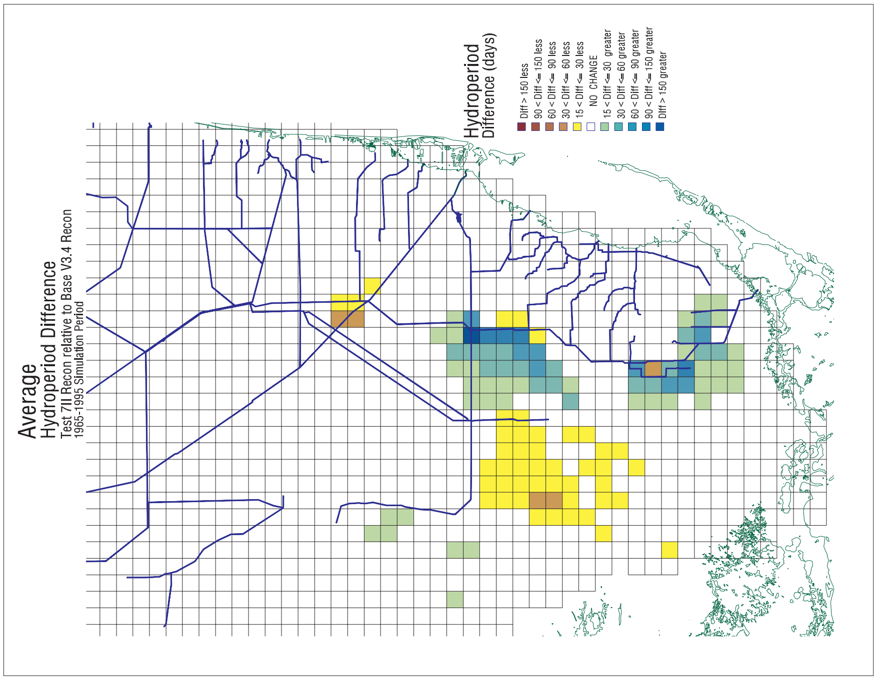


(b) Difference from1983 Base

Figure 8: Average annual hydroperiods predicted for Test 7 Phase I and difference from 1983 Base Condition.

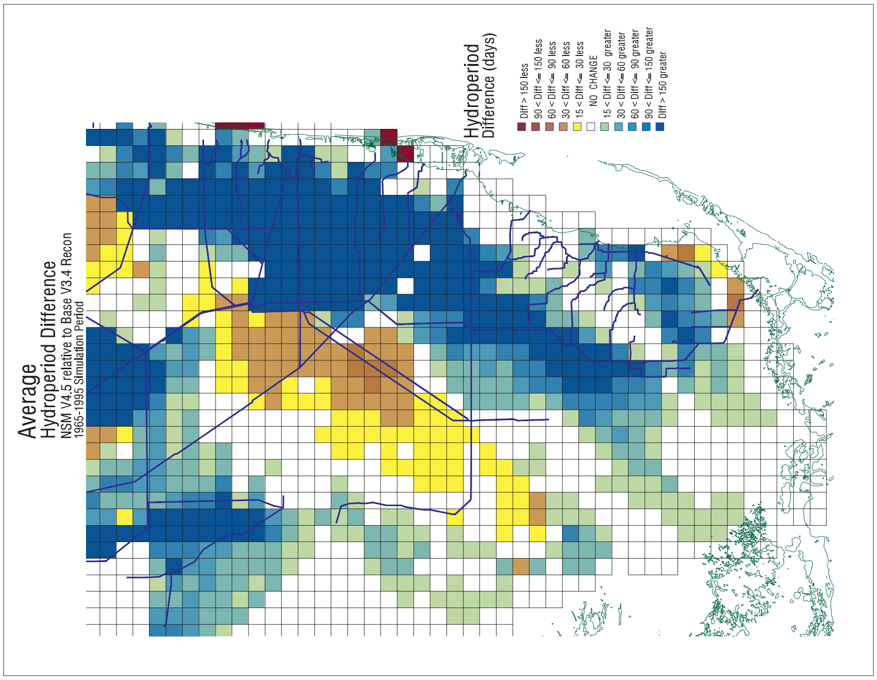


(a) Test 7 Phase II

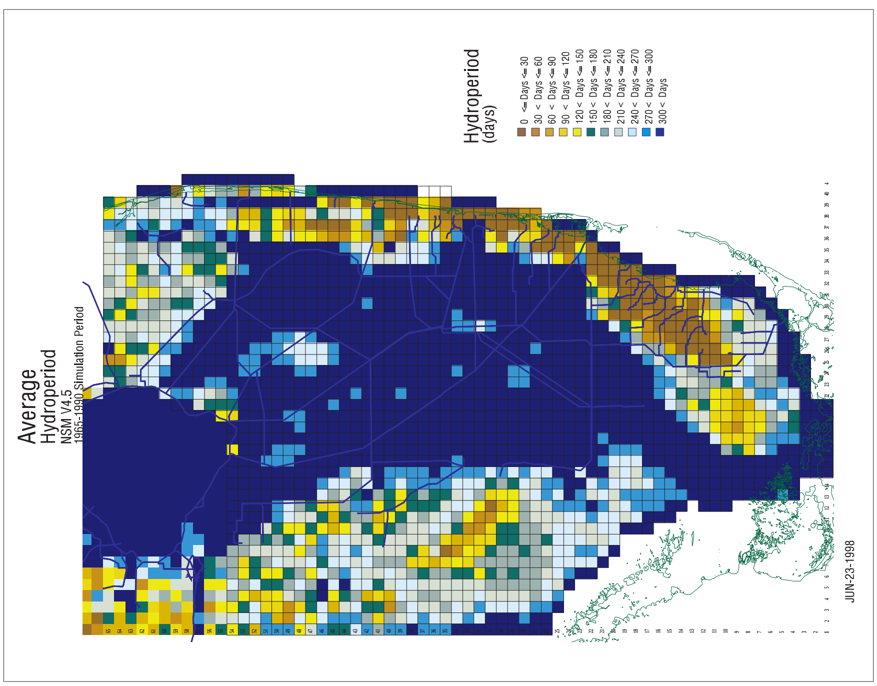


(b) Difference from1983 Base

Figure 9: Average annual hydroperiods predicted for Test 7 Phase II and difference from 1983 Base Condition.

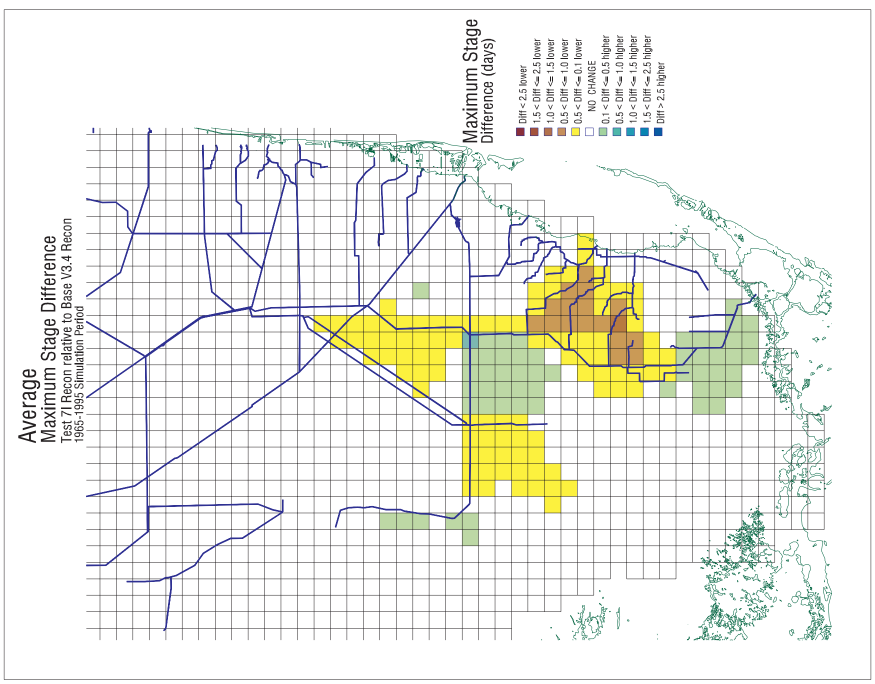


(b) Difference from1983 Base

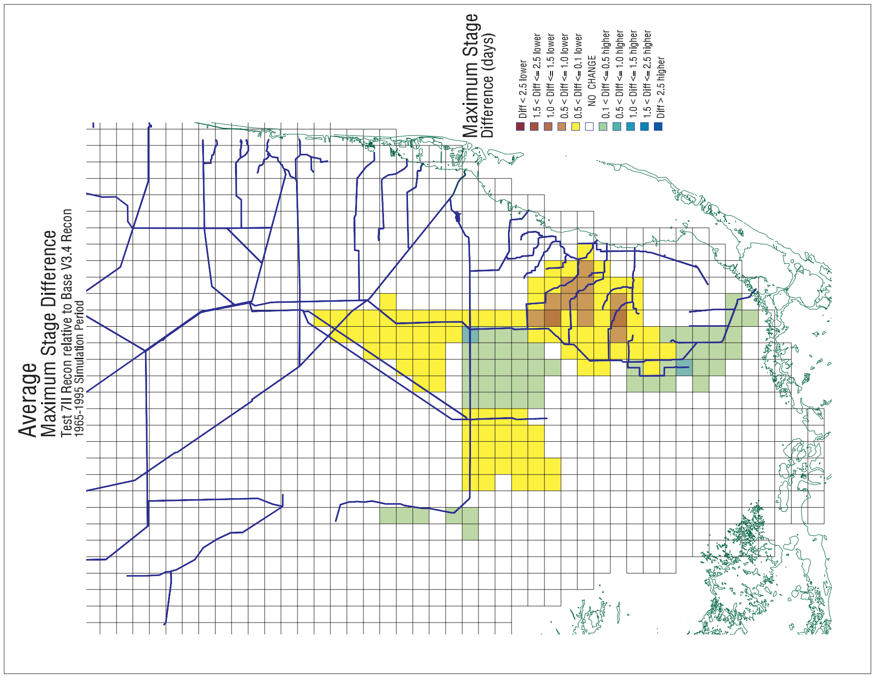


(a) NSM

Figure 10: Average annual hydroperiods predicted for NSM and difference from 1983 Base Condition.



(a) Test 7 Phase I



(b) Test 7 Phase II

Figure 11: Comparison of differences in the average annual maximum stage for Test 7 Phases I and II relative to the 1983 Base.

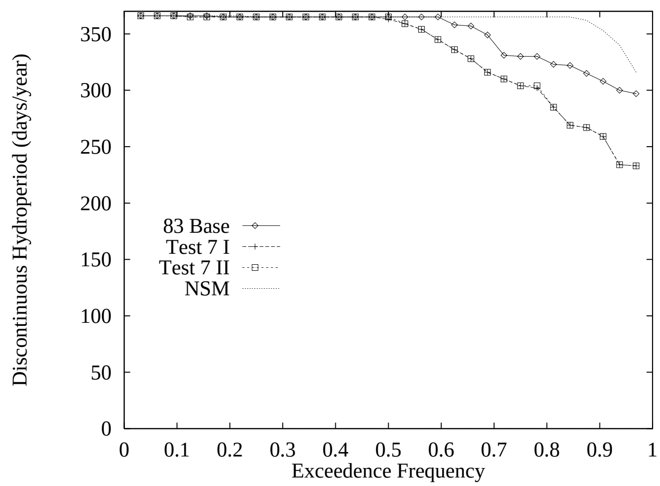


Figure 12: Annual hydroperiod for western Shark Slough (Indicator region 10).

look at those measures in an area predicted to be drier: Indicator Region 10 (see Figure 48 on page 62).

Figure 12 is a frequency of days per year that this region has ponded water (hydroperiod.) Note that the hydroperiod difference between the 1983 Base and Test 7 Phases I and II increases for drier conditions. This lowering of water levels during dry periods is also borne out in the maximum and minimum annual stages. Again, the relative difference between 1983 Base and Test 7 tends to increase as conditions become drier.

The flow volume across Tamiami Trail, shown in Figure 15, also tends to support the contention that Test 7 and the 1983 Base flow volumes differ most during dry years. The 1983 Base and Test 7 tend to the same annual flow volume as conditions become wet (right side of figure) and differences increase as conditions become drier. The minimum delivery of 265,000 acre-ft per year is clear in the 1983 Base as the flat part of the curve at return periods 1-in-5 year droughts.

A look at the daily summary of S-12/S-333 discharges reveals another important differences in S-12 flows between the 1983 Base condition and Experimental Water Deliveries. Figures 16–17 are the daily time series for the S-12 and S-333 discharges for the 1983 Base and Test 7 Phase I. The Test 7 discharges are dramatically less “spikey.” The transition between discharges is much smoother, resulting in a flow hydrograph much closer to a natural response. The latter difference is due almost entirely to the implementation of additional zones in the WCA-3A regulation schedule (Figure 4 on page 27). This is certainly real and

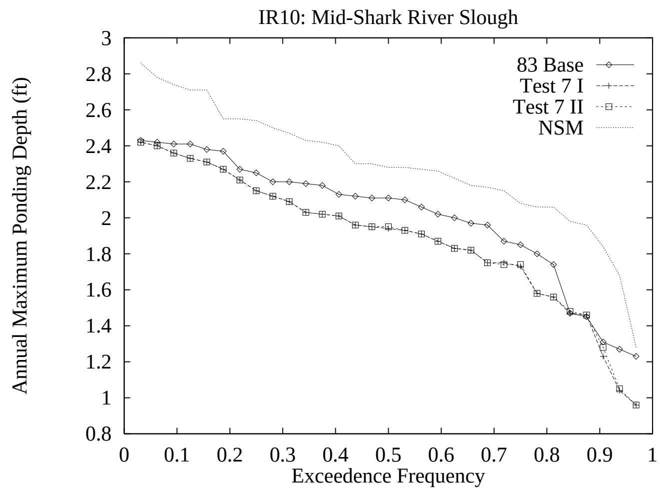


Figure 13: Annual maximum ponding depth for western Shark Slough (Indicator region 10).

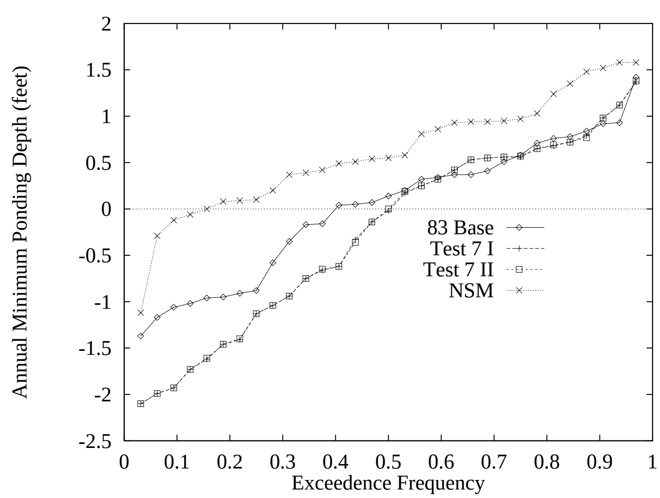


Figure 14: Annual minimum ponding depth for western Shark Slough (Indicator region 10).

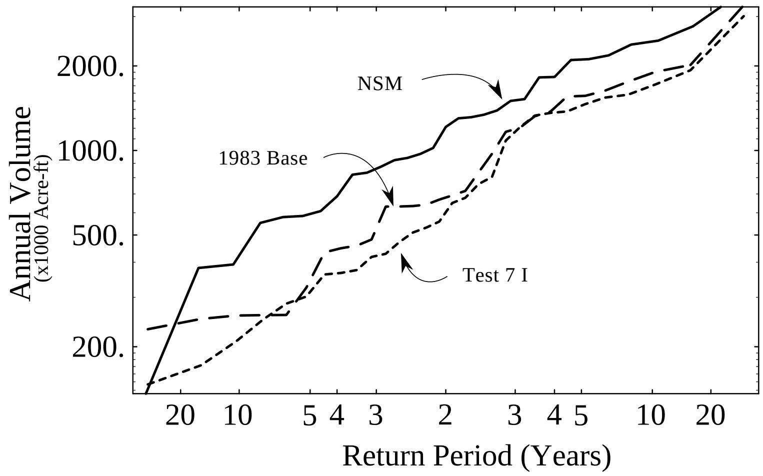
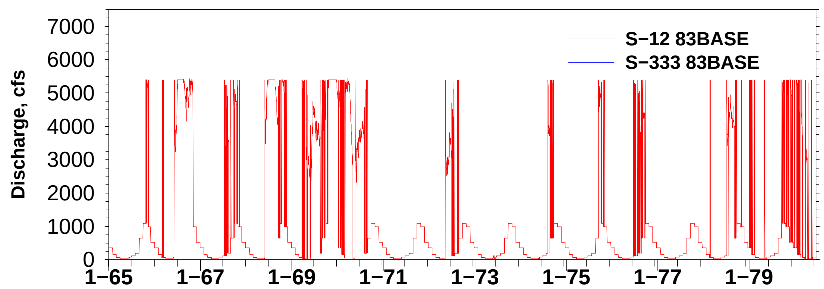
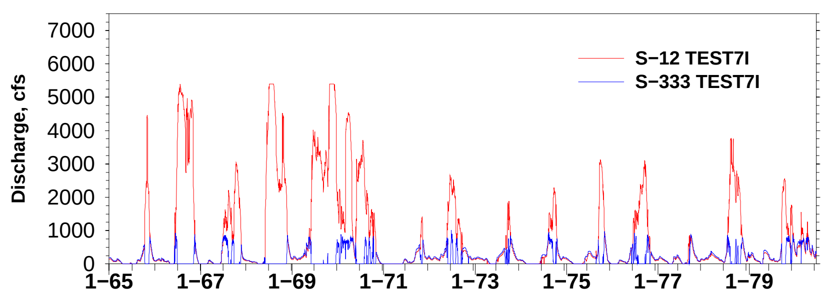


Figure 15: Exceedence frequency for annual flow volume across Tamiami Trail between L30 and 40 Mile Bend.

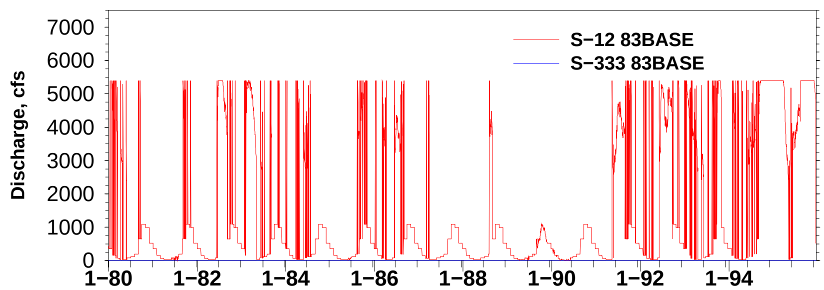


(a) 1983 Base

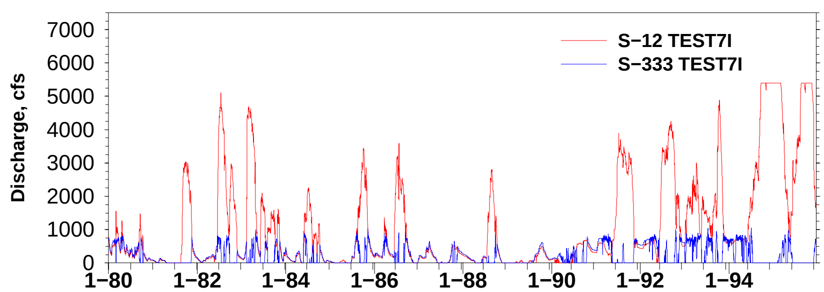


(b) Test 7 Phase I

Figure 16: Daily Tamaimi Trail discharges for 1983 Base and Test 7 Phase I for 1965–1981.



(a) 1983 Base



(b) Test 7 Phase I

Figure 17: Daily Tamaimi Trail discharges for 1983 Base and Test 7 Phase I for 1981–1995.

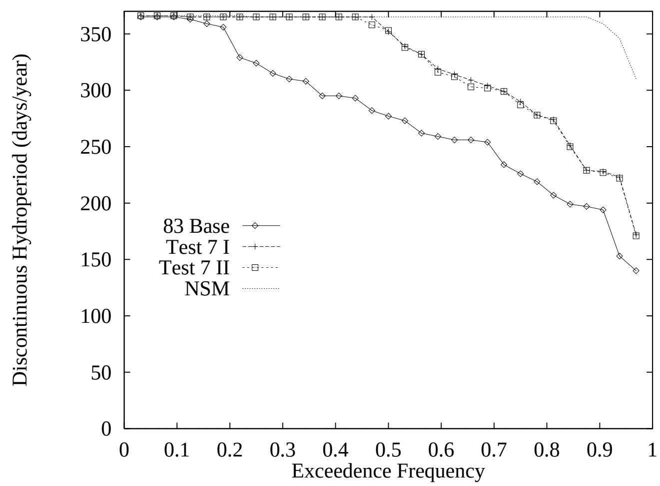


Figure 18: Annual Hydroperiod for Northeast Shark Slough (Indicator region 11).

one of the most important hydrologic benefits of the entire Experimental Water Deliveries Program.

The simulations also clearly suggest that water levels in Northeast Shark Slough are expected to increase, and as a result, seepages east along L-31N will increase and L-31N canal stages could possibly be affected. Moreover, the water budgets suggest large increases in L-31N flows at S-331. The stage effects in Northeast Shark Slough can be measured in a similar way to western Shark Slough; Figures 18 thru 20 are the exceedence frequencies hydroperiod, annual maximum and annual minimum ponded depths. These measures indicate that, indeed, Northeast Shark Slough is wetter, on the average, under Experimental Water Deliveries than the 1983 Base. The annual minimum stage, Figure 20, shows a dramatic increase in the annual minimum stage under all but the most extreme wet and dry conditions. This is apparently another important benefit of the Experimental Water Deliveries. However, Figure 19 would suggest that, under wetter than average conditions, there is very little to no difference between the 1983 Base and Test 7. The constraints on L-29 and G-3273 completely curtail S-333 inflows for the wettest 25% of the years.

The Experimental Water Deliveries program also has a number of operational features that lower water levels in the L-31N basin, particularly by S-331 pumping and lower S174/S176 open criteria. A full and complete analysis of the flood control impacts from the Experimental Water Deliveries is properly the domain of models other than the SFWMM. The SFWMM can only give a general overview, and indicate possible effects and trends. However, analyses of trends and general effects are potentially useful here, if only to get an

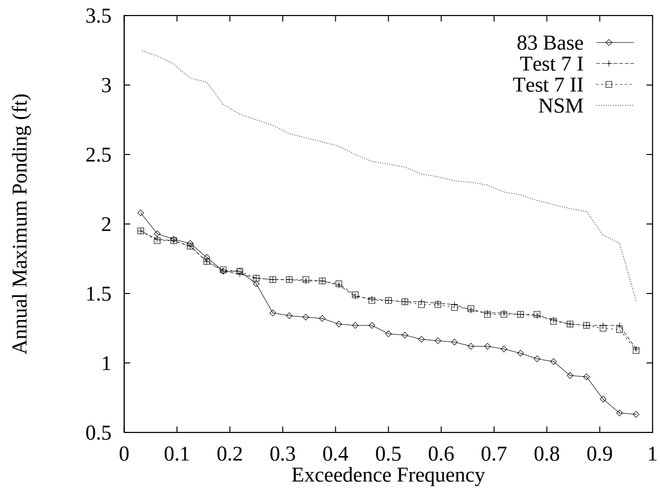


Figure 19: Annual Maximum Ponding Depth for Northeast Shark Slough (Indicator region 11).

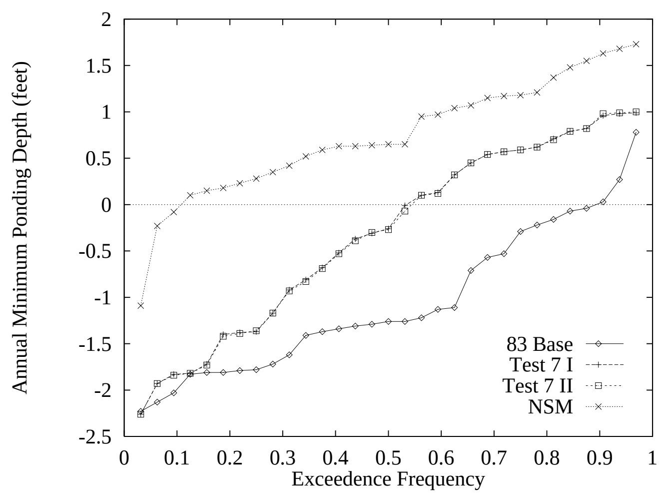


Figure 20: Annual Maximum Ponding Depth for Northeast Shark Slough (Indicator region 11).

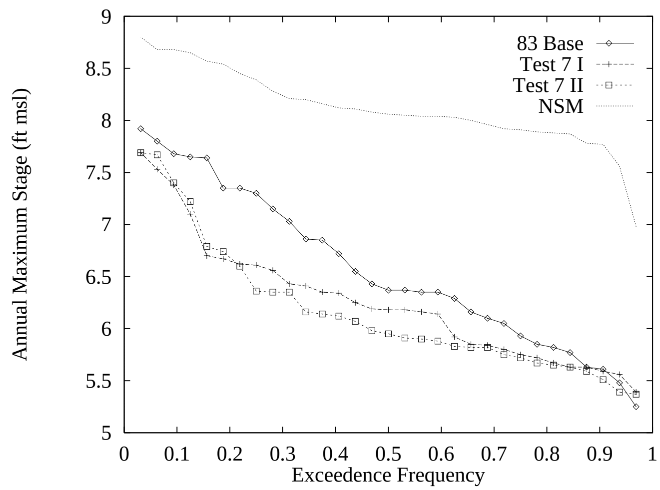


Figure 21: Test 7 annual maximum stage for the 8.5 SMA.

indication of implications for Rocky Glades and the 8.5 Square Mile Area. Figure's 21–26 are the general performance measures which look at water levels related to the potential for flooding. Included here is the annual maximum stage, the maximum ponding levels exceeded for 30 consecutive days, and the annual hydroperiods. Figure 22 would indicate that, under pre-drainage conditions, water would be ponded on the surface for more than 30 days per year in 19 of 20 years (exceedence frequency of 0.95) while the 1983 Base showed ponded water for more than 30 days only 1 year in 20 (exceedence frequency of 0.05). Test 7 Phase I shows that the water levels probably do not exceed 1.2 feet below the ground for more than 30 consecutive days. Figure 23 shows the result of C&SF Project in terms of hydroperiods, or expected days that land will be flooded per year. Prior to drainage, the area was flooded 7 to 8 months per year, on the average. In 1983 Base, it takes very wet years (1-in-5 to 1-in-10) to produce any ponded water. Figures 21–26 would also suggest that the Experimental Water Deliveries operations in L-31N drastically overcompensate for the effects of increased inflows into Northeast Shark Slough. For all of the above measures, Test 7 Phase I is well below the 1983 Base condition. That is, Experimental Water Deliveries operational rules provide a clear flood control benefit even during conditions when Northeast Shark Slough is not affected.

Another important general indication from the above figures is that Test 7 Phase II is generally much closer to the 1983 Base than Test 7 Phase I in the Rocky Glades, but has little apparent effect in the 8.5 Square Mile Area. More detailed modeling would be required to given a clearer indication of the specific relationship. However, it is intuitively clear that, since canal stages for L-31N south of S-331 in Test 7 Phase II are closer to the 1983 Base

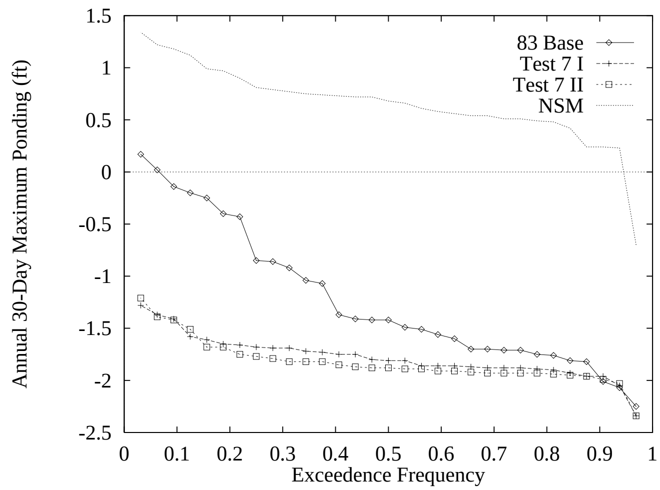


Figure 22: Test 7 ponded depth which is exceeded for 30 continuous days per year for the 8.5 SMA.

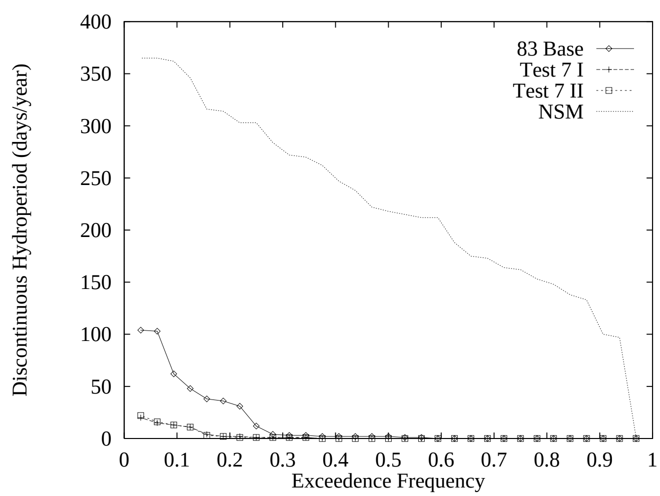


Figure 23: Test 7 annual hydroperiod for the 8.5 SMA.

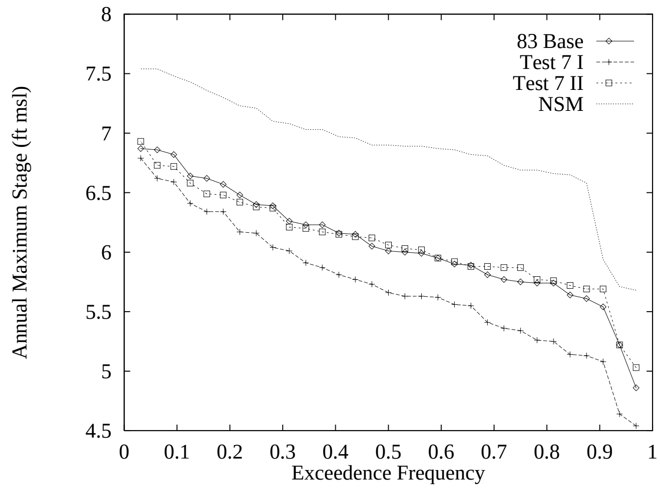


Figure 24: Test 7 annual maximum stage for the Rocky Glades

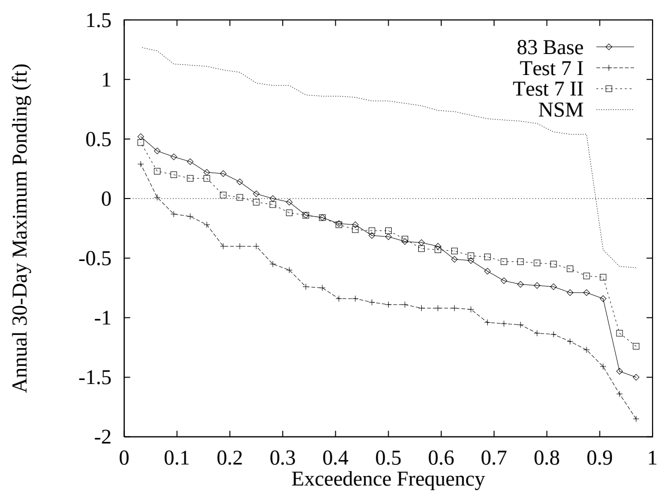


Figure 25: Test 7 ponded depth which is exceeded for 30 continuous days per year for the Rocky Glades

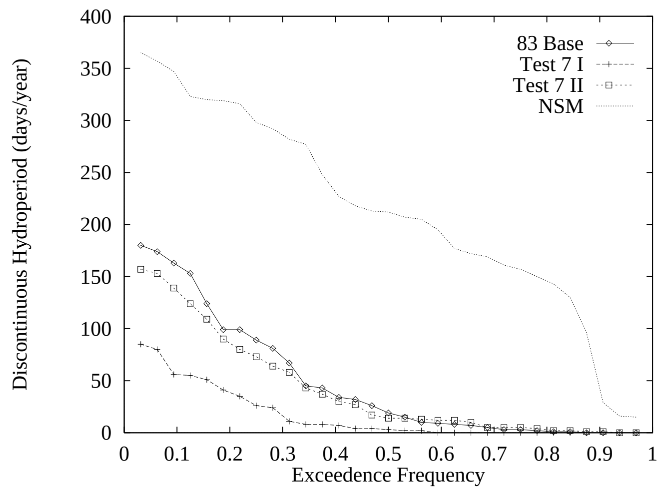


Figure 26: Test 7 annual hydroperiod on the Rocky Glades

condition than Test 7 Phase I, general indicators of water levels in the Rocky Glades should be closer as well. Since there is no effective difference in operational rules between Test 7 Phases I and II for S-331 and G-211, one would expect the two Test 7 phases to be similar, and they are. In that sense, the modeling confirms the expected outcomes.

At this point, we should restate that all of the above analysis is entirely predicated on the simulation results for the SFWMM and the NSM, not from an analysis of the extensive field data. These observed data have been collected and analyzed in a number of reports. MacVicar and VanLent [1984], MacVicar [1985], Neidrauer and Cooper [1989], Everglades National Park [1995], and US Army Corps of Engineers [1997b] all contain extensive analysis of the observed hydrologic information. An analysis of the observed hydrologic information would be extremely useful in validating and interpreting the simulation results, particularly in the context of an ecological analysis.

In general, the above cited reports recognize the potential for increased water levels in Northeast Shark Slough, but have not found that the current operational regime results in increases in water levels as large as those predicted in these simulations. For example, Figures 27 –29 are the same hydrologic performance measures shown in Figures 21–26 on pages 43 thru 46, using observed data at G-618. This data shows some of the effects predicted by the SFWMM for Northeast Shark Slough. However, the observed effects are not nearly as large as predicted by modeling, seen in Figures 21–26 on pages 43 thru 46.

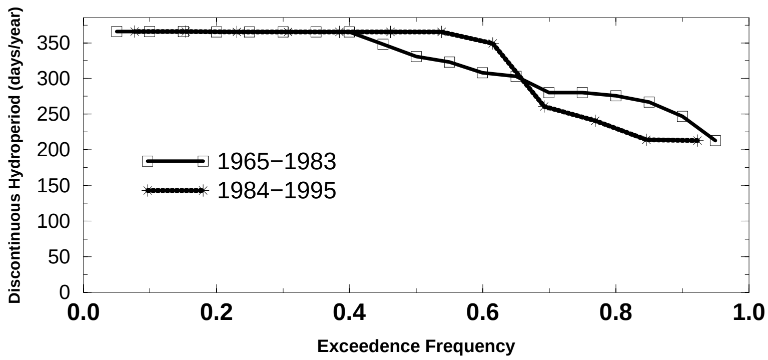


Figure 27: Annual Hydroperiod for observed G-618 data. See Figure 1 for location.

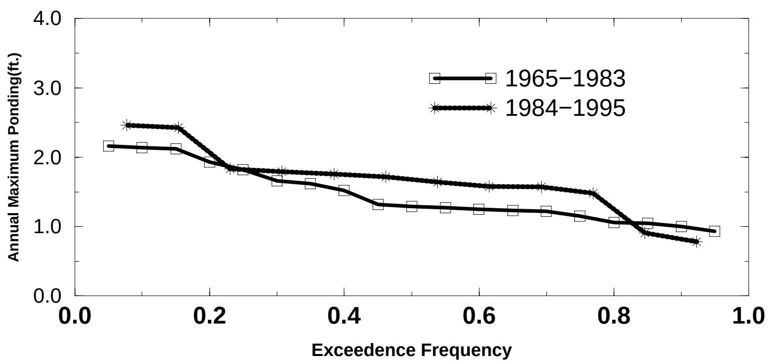


Figure 28: Annual maximum ponding depth for observed G-618 data

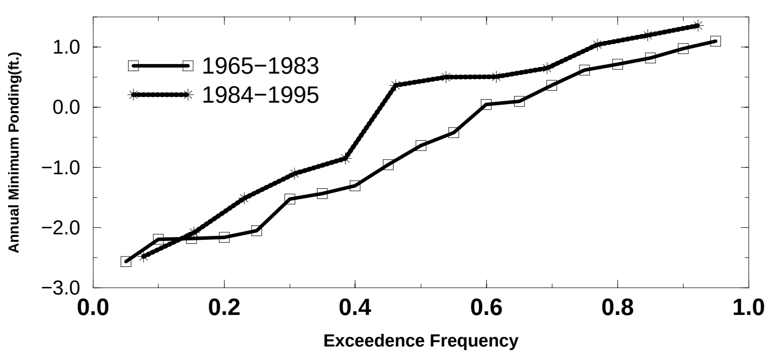


Figure 29: Annual minimum ponding for observed G-618 data.

Summary

With respect to the hydrologic analysis, we have the following observations:

- According to ENP SFWMM simulation results, the primary benefits of the Experimental Water Deliveries are

  - Decreased "spikiness" of the S-12 discharges related to the the additional zones in the WCA-3A regulation schedule,
  - Improved Taylor Slough hydrologic regimes related to the L-31W operations,
  - Improved hydroperiods in Northeast Shark Slough.

  The first two are documented with observed data, while the third is has not been documented with actual data to the extent predicted in the simulations.

- According to ENP SFWMM simulation results, the primary drawbacks of the Experimental Water Deliveries Program are

  - Annual average flow volumes into Everglades National Park and toward the Shark Slough estuaries decrease relative to the Minimum Delivery Schedule.
  - The decrease in flows into Shark Slough results in drier conditions in western Shark Slough during average and below average periods.
  - Experimental Water Deliveries has resulted in shorter hydroperiods and lower water levels west of L-31N and WCA-3A in wetlands of periphery NESS, the Rocky Glades and Northern Taylor Slough.

- The Experimental Water Deliveries Program has had no effect in the following areas:

  - During wet periods, flow volume, timing, and distribution across Tamiami Trail and the S-12 and S-333 structures are similar for Experimental Water Deliveries and for the 1983 Base condition.
  - During wet periods, water levels under Experimental Water Deliveries are similar to the 1983 Base for western Shark Slough and Northeast Shark Slough.
  - Northeast Shark Slough inflows are completely curtailed, and therefore, have little benefit, in the wettest 25% of the years.

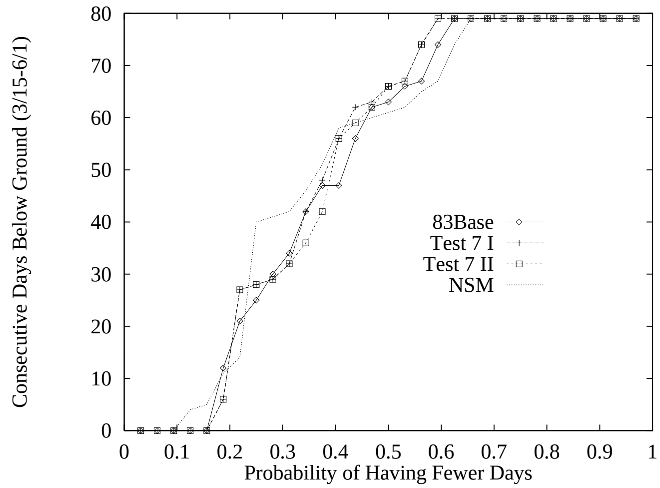


Figure 30: Return frequencies for number of consecutive days when water levels are below ground between March15 and June 1 for sparrow habitat A.

2.3 Effects on Endangered Species

2.3.1 The Cape Sable Sparrow

According to Curnutt and Pimm [1993], the Cape Sable sparrow population is distributed among six subpopulations; the location of these subpopulations is shown in Figure 2. The sparrows typically nest between March 15 and the onset of the wet season, which hydrologists typically take as June 1. Moreover, for courtship and nesting activity to commence, water levels over the sparrow habitat must recede to and stay below 4 inches (10 centimeters). Therefore, one important potential hydrologic measure of the potential for sparrow nesting success is to determine the number of consecutive days between March 15 and June 1 that water levels are below ground surface. This is an indirect and somewhat conservative measures of the number of days potentially available for sparrow courtship and nesting.

Figure 30–35 are plots showing the frequency of consecutive days when water levels are below ground in the period between March 15 and June 1. The interpretation of the graph is as follows. The $y-$axis is the number of consecutive days between March 15 and June 1 that water levels are below ground surface. The x-axis probability that, in any given year, there will be y days or fewer. For example, in Figure 33, the frequency of 40 days or less is approximately 0.20, or about 1-year-in-5, for the 1983 Base, while having 30 days or less is about 0.01, or 1-year-in-10. These graphs are related to, but not a direct measure of,

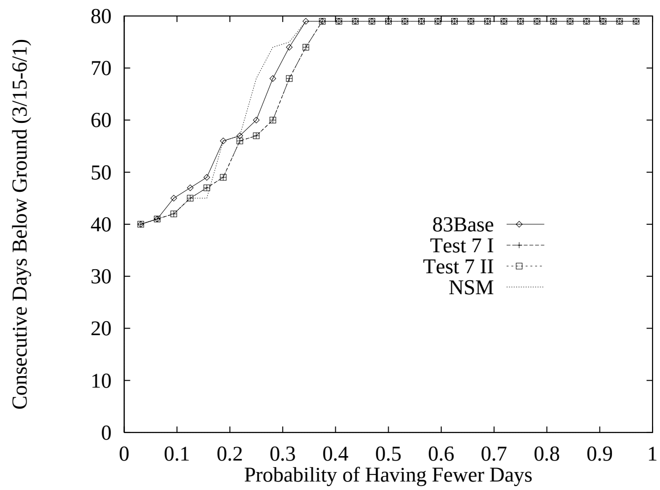


Figure 31: Return frequencies for number of consecutive days when water levels are below ground between March15 and June 1 for sparrow habitat B.

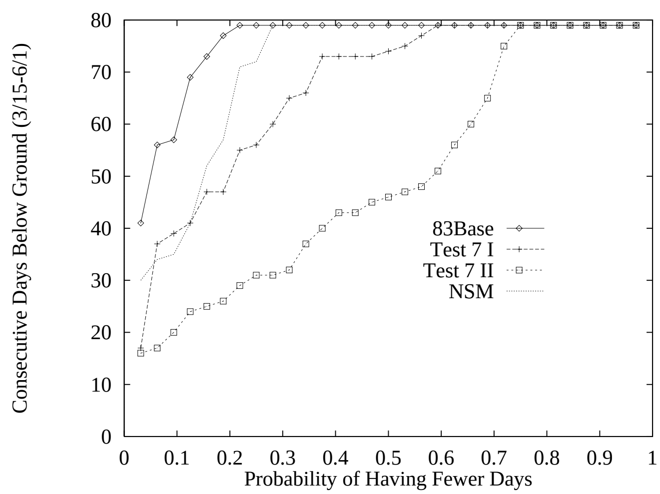


Figure 32: Return frequencies for number of consecutive days when water levels are below ground between March15 and June 1 for sparrow habitat C.

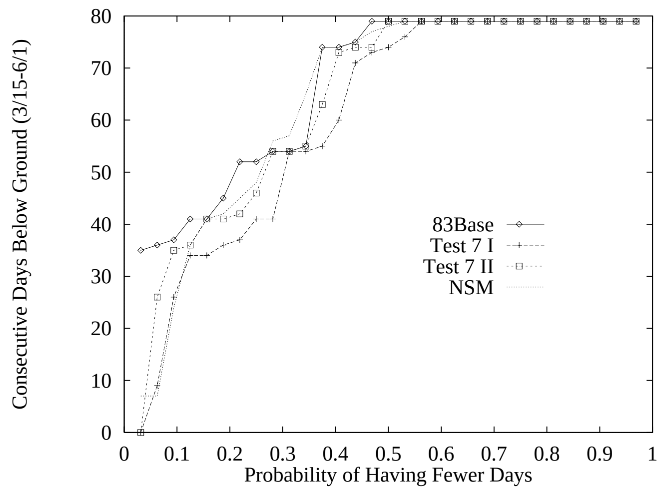


Figure 33: Return frequencies for number of consecutive days when water levels are below ground between March15 and June 1 for sparrow habitat D.

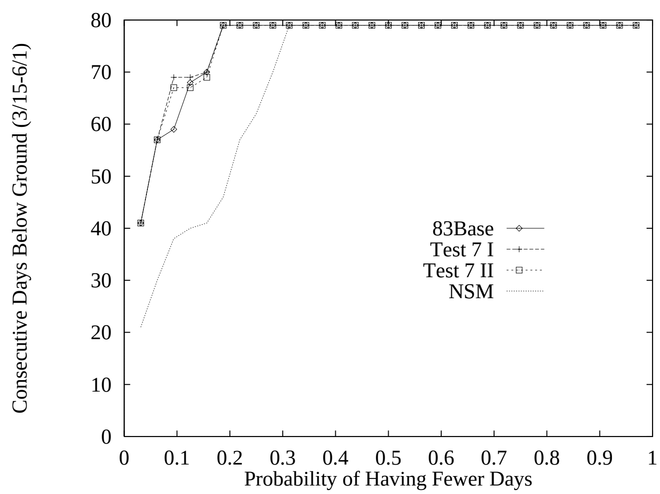


Figure 34: Return frequencies for number of consecutive days when water levels are below ground between March15 and June 1 for sparrow habitat E.

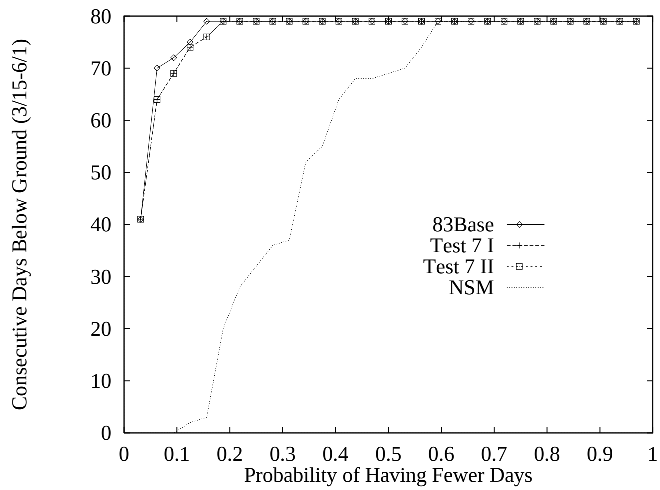


Figure 35: Return frequencies for number of consecutive days when water levels are below ground between March15 and June 1 for sparrow habitat F.

the likelihood of having an adequate window for nesting.

From the information in Figures 30–35, we draw the following inferences. First, Test 7 did not substantially change the window of nesting availability for subpopulations A, B, E, or F. Two subpopulations, C and D, saw decreases in their window of nesting opportunity.

Subpopulation C is on the flanks of Taylor Slough, and Test 7 Phase I and Phase II have substantially more flows through Taylor Slough than the 1983 Base Condition. Subpopulation D, located near Structure 18C, has experienced a potentially significant decrease in nesting opportunity as defined by this metric. One difference between Test 7 Phase I and the 1983 Base Condition is that S-18C headwater is slightly higher (2.6 ft msl vs. 2.4 ft msl open criterion). This slight increase in canal stages was in partial compensation for the substantial lowering of canal stages further north, in L-31N and C-111 canals (see Figure 1). The lowering of canal stages and operation of S-331 pump station had the effect of moving large volumes of flows into the lower C-111 canal. These two factors are the primary reasons for the wetter conditions and reduced nesting opportunity seen for subpopulation D. Test 7 Phase II attempts to redress this problem by diverting flows into Taylor Slough with S-332D and by increasing canal stages in L-31N. The effect net effect is that Test 7 Phase II increases the nesting opportunity relative to Phase I, but is still substantially below the 1983 Base Condition.

According to Lockwood *et al.* [1997], the sparrow also has the potential to produce more

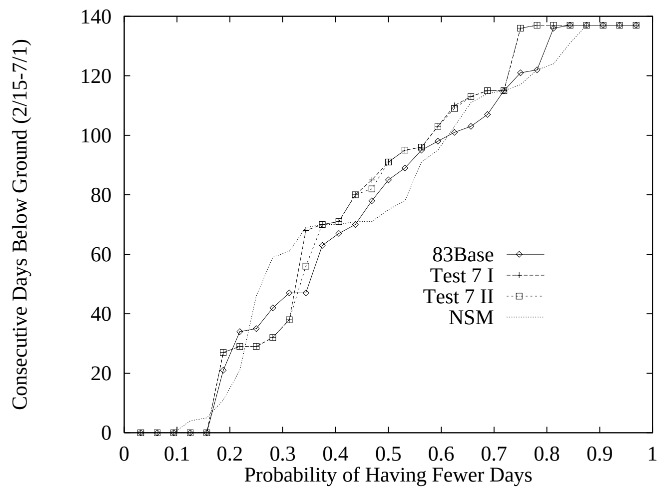


Figure 36: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat A.

than a single clutch in a given nesting season. Therefore, another potentially important hydrologic metric is the number of nesting days between February 15 to July 1, which incorporates most of the window when sparrows have been observed nesting. Figure 36–41 are plots showing the frequency of days when water levels are below 10 cm in the period between February 15 to July 1. These graphs show substantially similar results to the March 15–June 1 measures. For populations A, B, and F, there is relatively little change between the 1983 Base Condition, Test 7 Phase I and Test 7 Phase II. Subpopulation D also has an overall decrease in nesting opportunity, but Test 7 Phase II shows a slight increase relative to Test 7 Phase I, while both Test 7 phases show a substantial decrease in nesting opportunity compared to the 1983 Base Condition.

Subpopulation C has an overall decrease in nesting opportunity. The stage targets used by the SFWMM for S-332D pumping are based upon the NSM water levels in Taylor Slough. In theory, Test 7 Phase II should match the NSM targets. Since it does not, this would suggest either the model is not performing particularly well for this area, or that dry season flood flows are controlling S-332D pumping. One can make no clear determination using the SFWMM; we would recommend the Corps' MODBRANCH model be employed to better predict hydrologic response in this area.

The number of available nesting days is not the only important hydrologic measure to determine the effects of the Experimental Water Deliveries Project on the Cape Sable sparrow. As described by Curnutt *et al.* [1998], the hydrologic regime required to maintain

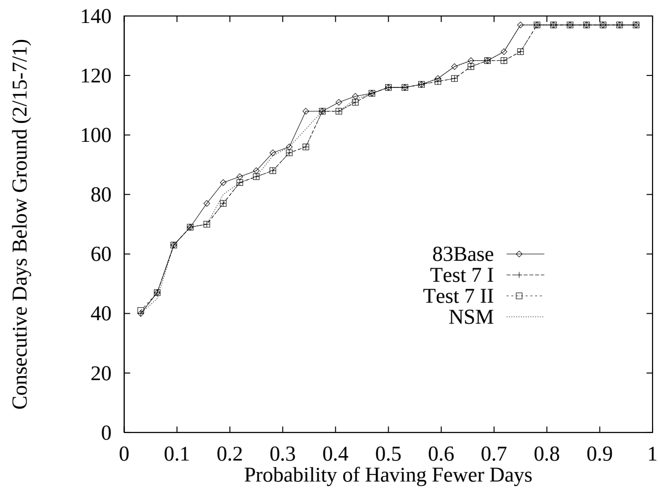


Figure 37: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat B.

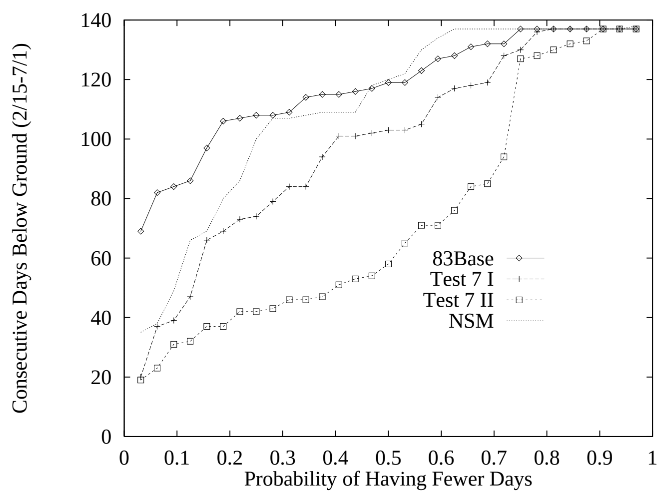


Figure 38: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat C.

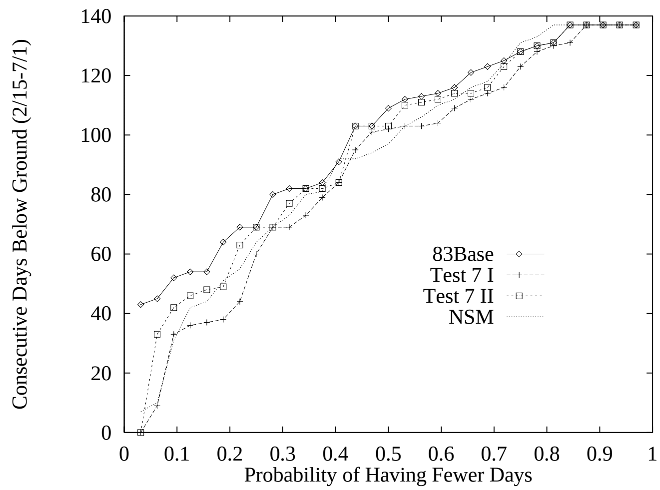


Figure 39: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat D.

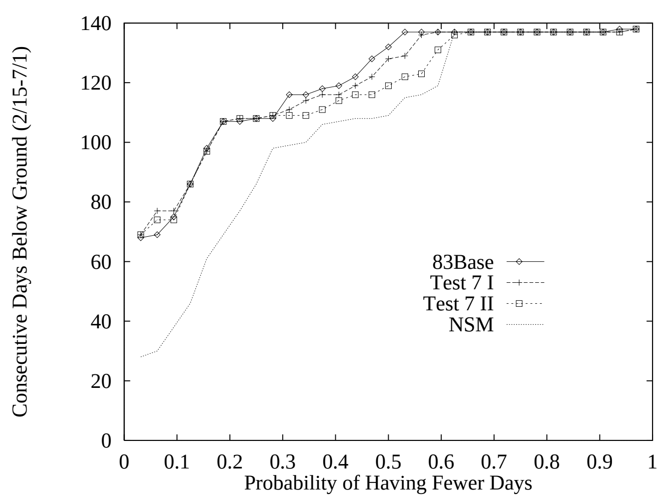


Figure 40: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat E.

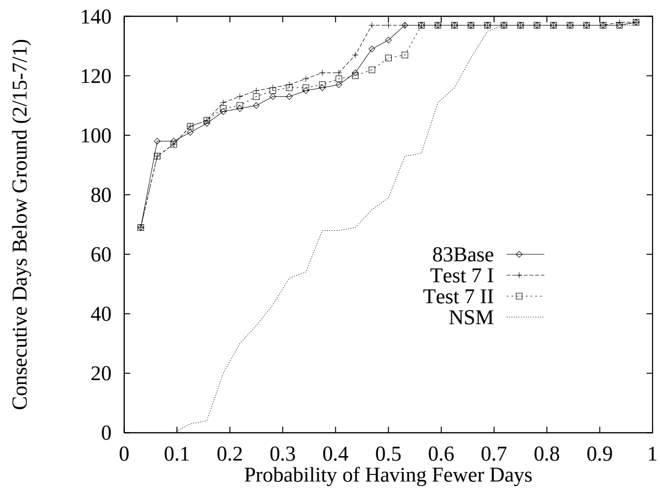


Figure 41: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat F.

the wet prairie habitat is also important. The decline of the eastern populations (C, D, E, and F) is related to the frequency of fire [Pimm, 1997], which is in turn, directly related to the hydroperiod, or number of days per year a marsh is flooded.

Figures 42–47 are measures of the number of days per year that one can expect the sparrow habitats to be flooded. The hydroperiods in the habitats of subpopulations A, B, and E are not significantly affected changed by the Experimental Program. The habitat of subpopulation C experiences an enormous change in hydroperiod in Test 7 Phase I; hydroperiods increase by approximately 2 months for any given return period. This is most likely a modeling artifact, and not necessarily a valid prediction. Further analyses should be undertaken specific to subpopulation C before drawing definitive conclusions. Subpopulation D habitat may experience hydroperiod increases up to 2 months in Test 7 Phase II relative to the 1983 Base Condition, although Test 7 Phase II will decrease this hydroperiod by about 2-3 weeks.

Subpopulation F has seen a dramatic decrease the the hydroperiod in Test 7 Phase I relative to the 1983 Base Condition. Lowering of water levels in the L-31N canal and large pumping volumes at S-331 to provide flood protection for the 8.5 Square Mile Area have resulted in a decrease hydroperiods, which is likely responsible for the high fire frequency and woody plant encroachment observed by Pimm [1997]. Test 7 Phase II improves the average and dry conditions, but the habitat is still considerably drier than the 1983 Base Condition during wetter than average periods.

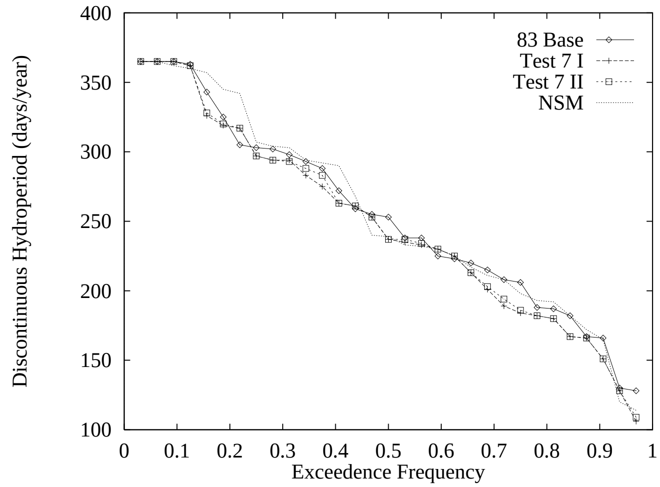


Figure 42: Hydroperiod frequencies for sparrow habitat A.

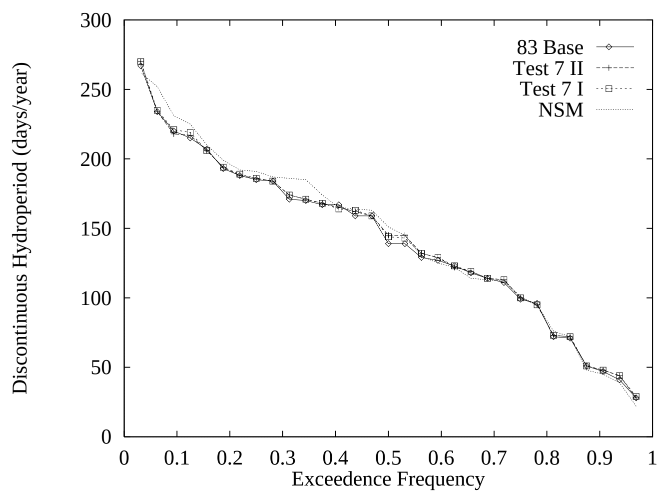


Figure 43: Hydroperiod frequencies for sparrow habitat B.

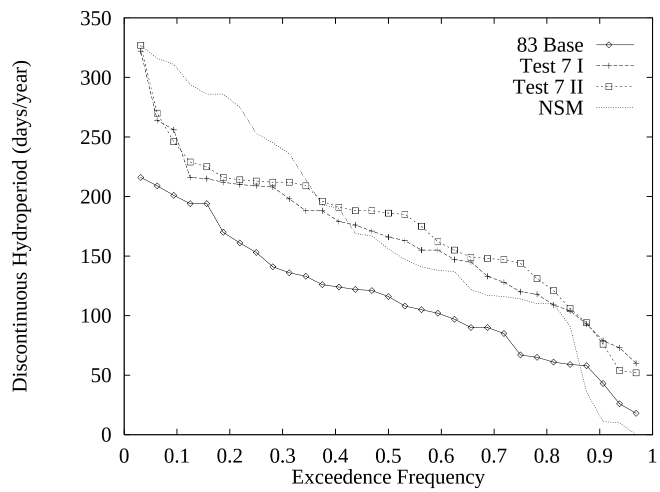


Figure 44: Hydroperiod frequencies for sparrow habitat C.

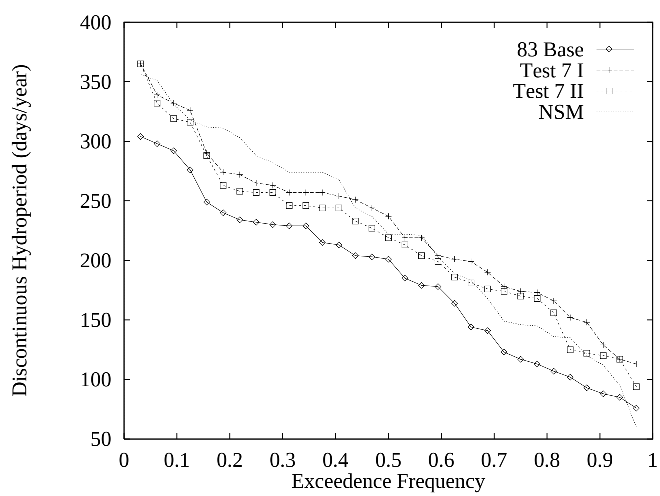


Figure 45: Hydroperiod frequencies for sparrow habitat D.

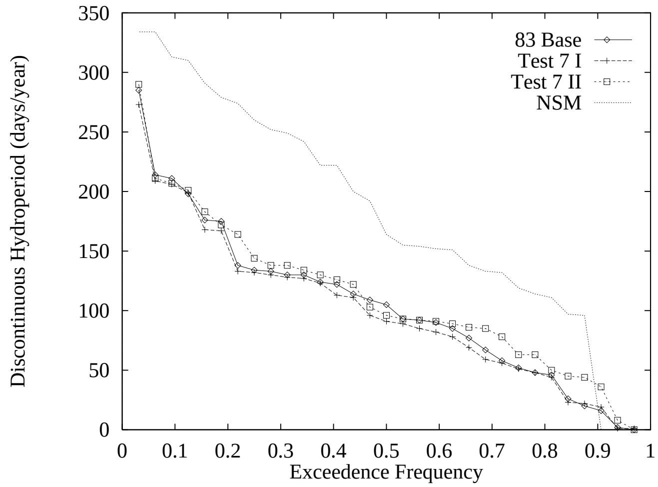


Figure 46: Hydroperiod frequencies for sparrow habitat E.

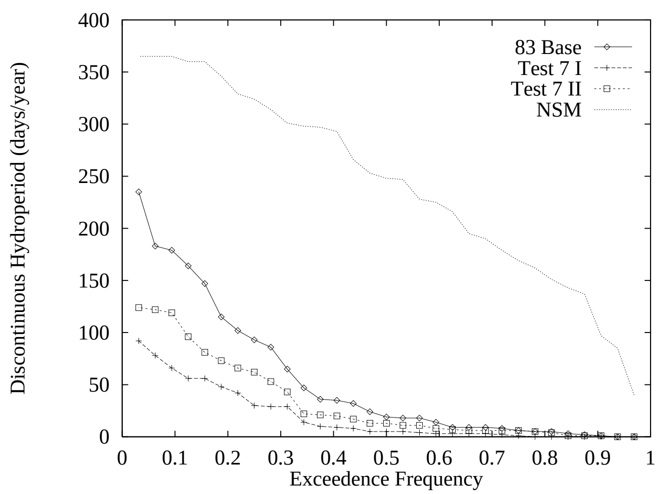


Figure 47: Hydroperiod frequencies for sparrow habitat F.

This latter finding is entirely consistent with the available field data. Van Lent *et al.* [1993] document the loss of sheetflow and decrease in hydroperiods in the Rocky Glades marshes subsequent to the L-31N canal stage lowering. Pimm [1997] asserts that increased fire frequency is primarily responsible for the decrease in numbers for the eastern sparrow subpopulations. Increased fire frequency and woody vegetation encroachment observed in the area are almost certainly a result the overdrainage resulting from the lowering of L-31N canal stages.

Summary

After analyzing the potential effects of the Experimental Water Deliveries Program on the Cape Sable sparrow, we have formed the following conclusions. First, it does not appear that Test Iteration 7 of the Experimental Water Deliveries Program significantly changes conditions during the nesting season in the western subpopulation, subpopulation A, relative to the 1983 Base Condition. That is, the rainfall formula for deliveries into Shark Slough, unchanged since Test Iteration 1, has not appreciably increased the fraction of flows into Northeast Shark Slough and away from the western sparrow habitats during wetter than average periods.

The Experimental Water Deliveries Program has not affected subpopulation B, the Ingraham Highway population. This area is far enough away from water control features that it remains unaffected by the Experimental Program.

The Experimental Water Deliveries Program effects on subpopulation C are not entirely clear. Computer simulation shows the habitat supporting subpopulation C becoming wetter than predicted by the Natural Systems Model. Subpopulation C is a very heterogeneous population. The modeling results conflict with field observations. South opf the pump station S-332, the habitat is too wet, contributing to changes in vegetation. North of the pump is too dry, contributiont to an increase of fire frequency and wood vegetation encroachment (Pimm, pers. com.) Other, more detailed models, will be required to determine the effects on this subpopulation.

The southeastern subpopulation, D, has been adversely affected by the Experimental Water Deliveries Program through Test 7 Phase I. The lower canal stages in L-31N stages have increased seepage out of northern Taylor Slough, and resulted in large flows into this area. According to Pimm (pers. comm.) the habitat associated with supopulation D is now almost entirely sawgrass. Vegetation change is likely a consequence of these large flows. These changes have resulted in a dramatic decline in subpopulation D. Phase II of Test 7 is also a significant improvement relative to Phase I. Moreover, Phase II conditions are very similar to that predicted by the Natural Systems Model. However, simulations also show an insufficient nesting window almost one year out of five for the NSM and Phase I, while the Base 1983 had an insufficient nesting window one year out of ten.

Subpopulation E has done much better in recent years. Pimm (pers. comm.) attributes this tentative success to the fact that E, in contrast to C, D, and F, has not repeatedly burned.

The northeastern subpopulation, F, has experienced adverse hydrologic changes under the Experimental Water Deliveries Program. The habitats supporting subpopulation F has become much drier than the 1983 Base condition because of the lower canal stages in L-31N from S-335 to S-176. This has likely increased the fire frequency, making the area unsuitable for the sparrow. However, Test 7 Phase II shows a significant improvement relative to Test Iteration Phase I.

2.3.2 Wood Stork

The wood stork performance measure proposed by Ogden [1998] for use in SERA and C&SF Restudy Project evaluations is as follows. The two hydrological indicators which best measure the recovery of optimum foraging conditions for storks for the restoration targets described above, are, (a) the measures of the volume of flow into the mainland estuaries downstream from the southern Everglades (two flow lines; one across the southern Shark Slough; one across the southern Taylor Slough), and (b) the measure of mean duration of uninterrupted surface hydroperiod in the central and southern Shark Slough (C&SF Restudy designated indicator regions 10 and 9 [see Figure 48]). The target proposed by Ogden [1998] is to meet NSM 4.5 predicted flow volumes and hydroperiod durations. The "score" for each water management scenario is the mean of the percentages of NSM targets for the four hydrological parameters (2 flow lines and 2 indicator regions). In calculating the final score, the mean of the flow volume scores is multiplied by 2. Greater weight for the estuarine target is appropriate, according to Ogden [1998], because achievement of the desired colony timing and location patterns may be dependent on estuarine conditions.

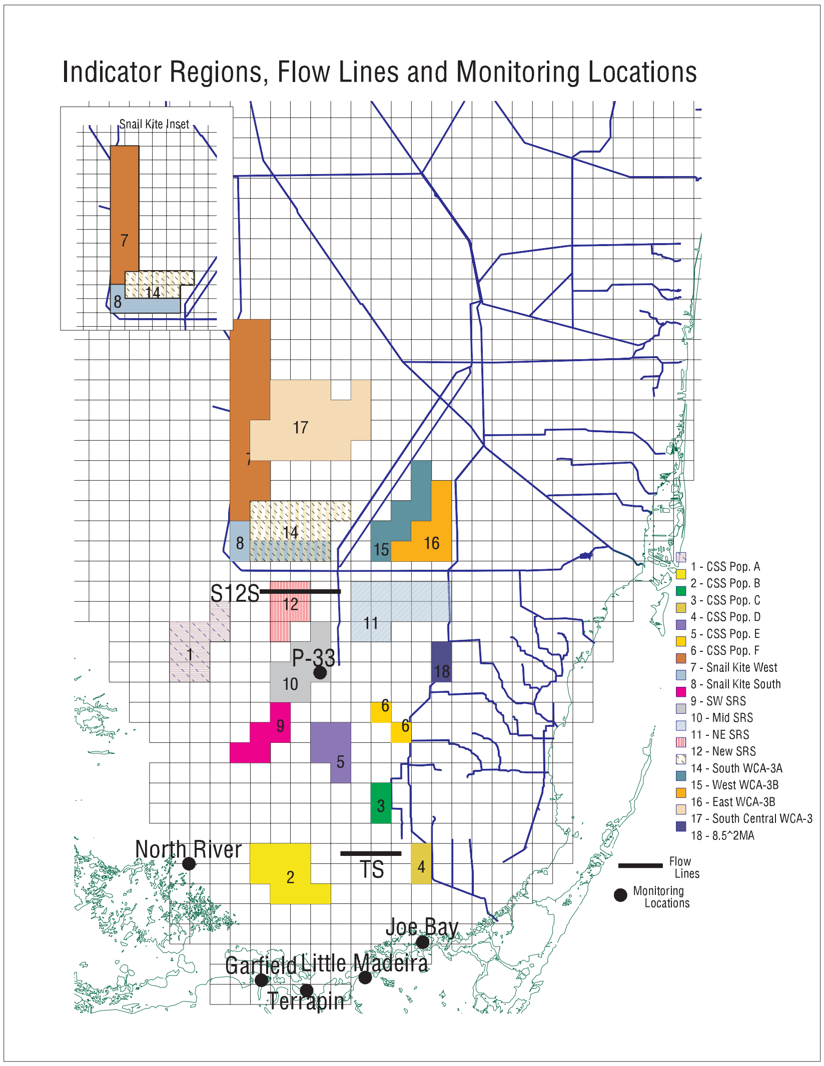


Figure 48: Indicator Regions used in this analysis.

The possible effects of the Experimental Water Deliveries Project on wood storks are estimated by applying the above proposed performance measures to simulated conditions under Test 7 Phase I and II to the 1983 Base Condition. Table 4 shows the results of this evaluation. According to this evaluation Test 7 Phases I and II provide average uninterrupted hydroperiods that are 26–32% of the NSM values. The 83 Base Condition provides hydroperiods that are 34–46% of NSM values. For average duration of uninterrupted hydroperiods, Test 7 Phases I and II perform worse than the 83 Base Conditions. The simulations suggest that for average annual flow volumes into the Shark Slough estuaries, Test 7 Phases I and II provide 58% of NSM values compared to 62% under the 83 Base Conditions. For Taylor Slough, Test 7 Phases I and II provide more than 100% of the volume of average annual NSM flows, while under the 83 Base Conditions flows are only 87% of NSM values. For flow volumes into the estuaries, Test 7 Phases I and II performs worse than the 83 Base Conditions in Shark Slough, and performs better than the 83 Base in Taylor Slough, matching or exceeding NSM values. Overall, when hydroperiods and flow volumes are considered together, the Experimental Water Deliveries Program is predicted to have worsened, by about 7%, wood stork foraging habitat conditions in the region of the traditional Shark Slough estuarine stork nesting colonies, compared to the 83 Base Conditions. This measure of decline (or improvement) assumes a linear relationship between hydropattern decline (or improvement) and habitat decline (or improvement). Also, it should not be assumed that a flow for Taylor Slough that averages well above NSM is beneficial for storks. It may be just as detrimental, ecologically, as below average (Ogden, pers. comm.) Overall when Shark Slough and Taylor Slough are evaluated together the Experimental Water Deliveries Program and the 83 Base are somewhat similar in performance.

Figures 49 and 50 shows the exceedence frequency curves for inundation length for Indicator Regions 9 (SW Shark River Slough) and 10 (Mid Shark River Slough). The inundation length is calculated by counting the total number of days in any given year that the average water level in the basin is above ground surface. The exceedence frequency is the likelihood that the region will experience a greater inundation length. Figures 49 and 50 shows that the Test Iteration 7 shows the area considerably drier than the 1983 Base Condition. For example, the chance of having an annual hydroperiod less than 10 months in Region 9 was approximately 1-in-5 under the 1983 Base, but 1-in-3 during Test 7. Region 10 went from a having a hydroperiod less than 10 months of 1-in-10 under the 1983 Base to 1-in-5 under Test 7.

These decreases in hydroperiods are consistent with the water budgets presented in Section 2.2. The volume of flow crossing Tamiami Trail has not increased under the Rainfall

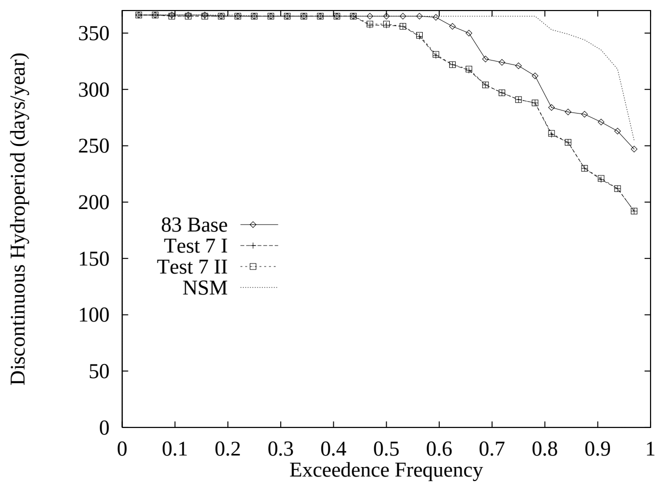


Figure 49: Exceedence frequency for hydroperiod for SW Shark River Slough (Indicator Region 9)

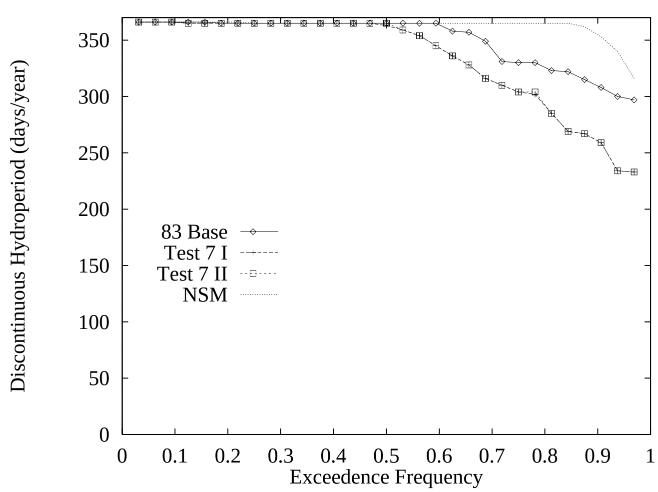


Figure 50: Exceedence frequency for hydroperiod for SW Shark River Slough (Indicator Region 10)

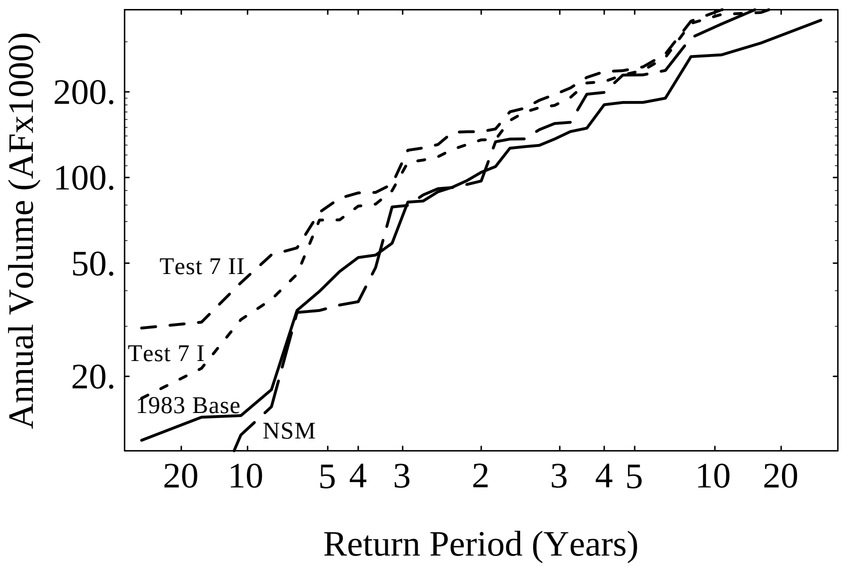


Figure 51: Frequency of annual freshwater inflows towards Florida Bay.

Plan, particularly during below average rainfall periods. However, the volume has been spread over more marsh, and has a longer flow path. Seepage to the east as well as evapotranspiration have increased relative to the base condition, resulting in lower flows to the estuaries. Figure 52 shows that this is indeed the case; flows towards Shark Slough estuaries have decreased during the Experimental Water Deliveries Program, according to these simulations. Flows towards the estuaries of Shark Slough and Florida Bay is the second performance measure used to predict wood stork response to hydrologic changes. Figures 51–52 are estimates of the return frequency for flows towards Florida Bay and Shark Slough, respectively. According to these estimates, annual flow volumes towards Florida Bay have increased relative to the 1983 Base condition. Freshwater inflows towards Florida Bay decrease slightly from Test 7 Phase I to Phase II. The likely explanation is that lower canal stages in L-31N and upper C-111 have drained the upper basins, and the flow has been routed into lower C-111. Flows towards Shark Slough have been reduced in Test 7 relative to the 1983 Base Condition, as discussed in Section 2.2.2.

2.3.3 Crocodile and Manatee

The possible effects of the Experimental Water Deliveries Project on crocodiles and manatees are estimated by comparing the salinity ranges expected under Test 7 Phase I and II to

Indicator	NSM	83 Base	Test 7 Phase I	Test 7 Phase II
IR 9 Inundation[a]	161	74	52	52
IR 10 inundation[b]	253	87	66	66
IR 9 Ratio to NSM	1.	0.46	0.32	0.32
IR 10 Ratio to NSM	1.	0.34	0.26	0.26
IR Mean	**1.0**	**0.43**	**0.29**	**0.29**
Taylor Slough[c]	138	120	173	162
Shark Slough[d]	1770	1096	1020	1025
Taylor Slough Ratio to NSM	1.0	0.870643	1.24952	1.16791
Shark Slough Ratio to NSM	1.0	0.62	0.58	0.58
Flow Mean	**1.0**	**0.75**	**0.92**	**0.88**
Total Score[e]	**1.0 (1.0)**	**0.63 (0.51)**	**0.71 (0.44)**	**0.68 (0.44)**

[a] Average number of weeks of continuous inundation
[b] Average number of weeks of continuous inundation
[c] Average Annual Flow Volume, in thousands of acre-ft
[d] Average Annual Flow Volume, in thousands of acre-ft
[e] Total Score calculated with and (without) Taylor Slough scores. Flow volume weighted by 2.0

Table 4: Summary of hydrologic performance measures related to the wood stork.

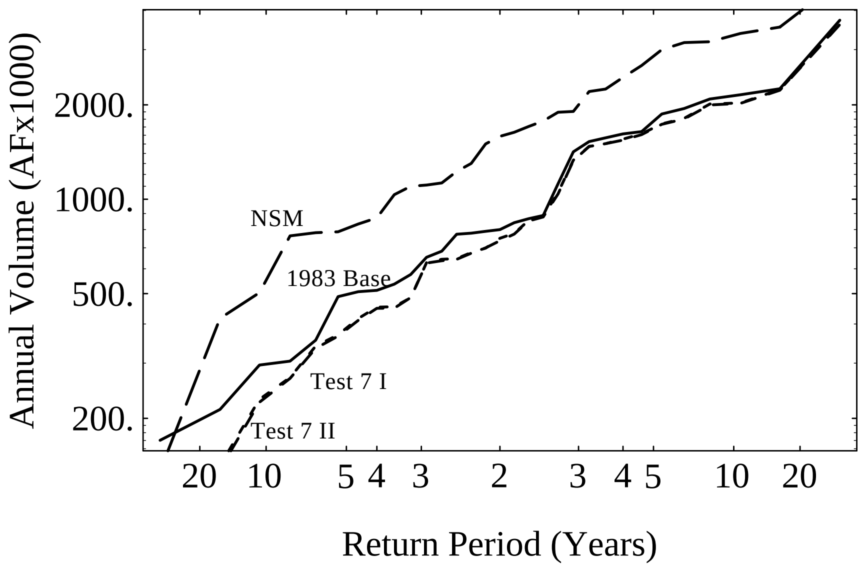


Figure 52: Frequency of annual freshwater inflows towards the Shark Slough estuaries.

the 1983 Base Condition. The performance measures, based on draft information [C&SF Restudy, 1998], are as follows

$$T_{\text{Joe Bay}} = 93.80906 - 12.74765 S_{\text{P33}} \quad (1)$$

$$T_{\text{Little Madeira}} = 104.66179 - 12.59143 S_{\text{P33}} \quad (2)$$

$$T_{\text{Terrapin}} = 104.06310 - 10.99946 S_{\text{P33}} \quad (3)$$

$$T_{\text{Garfield}} = 98.55244 - 10.08526 S_{\text{P33}} \quad (4)$$

$$T_{\text{North River}} = 86.59670 - 11.44561 S_{\text{P33}} \quad (5)$$

where T is average monthly salinity at the stations indicated with the subscript and S_{P33} is the average monthly stage at P33. The salinity stations and P33 are located in Figure 53.

The percent of months in each salinity category for five selected basins is shown in Figures 54–58.

The desired condition is to increase the percent of months in the low salinity category and reduce the percent of months in the high salinity category. According to these simulations, Test 7 Phases I and II increase the percent of months in the high salinity category and reduce the percent of months in the lower salinity category compared to the 1983 Base Condition. According to these simulations, both Test 7 Phases I and II produce somewhat less suitable crocodile and manatee habitat than under the 1983 Base Condition.

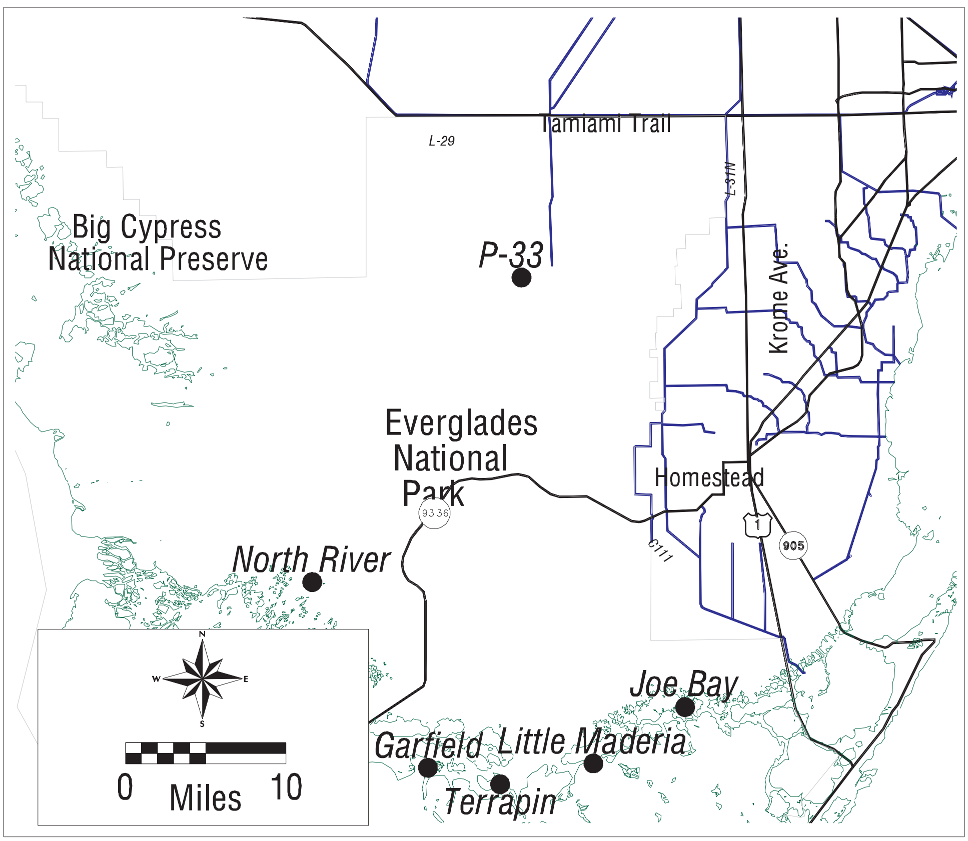


Figure 53: Location of the salinity monitoring sites and P-33.

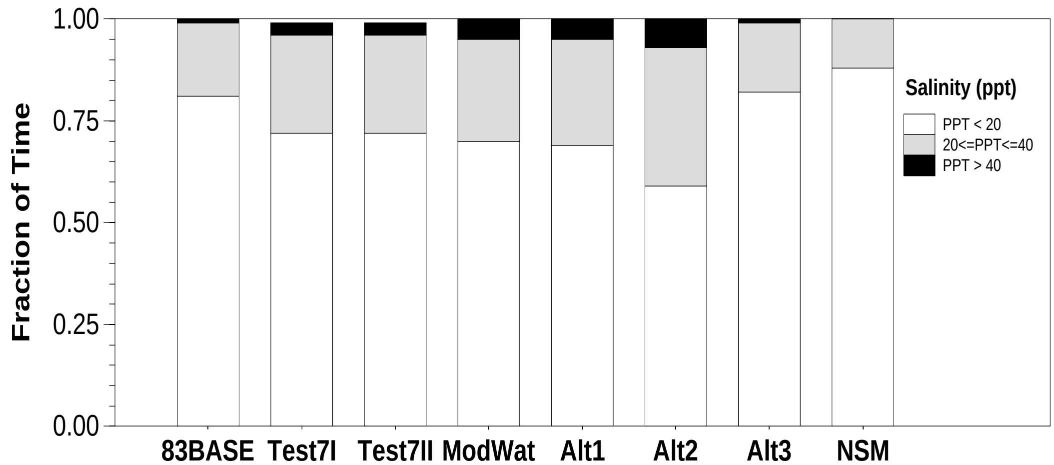


Figure 54: Salinity estimate for Joe Bay based upon P33 stages.

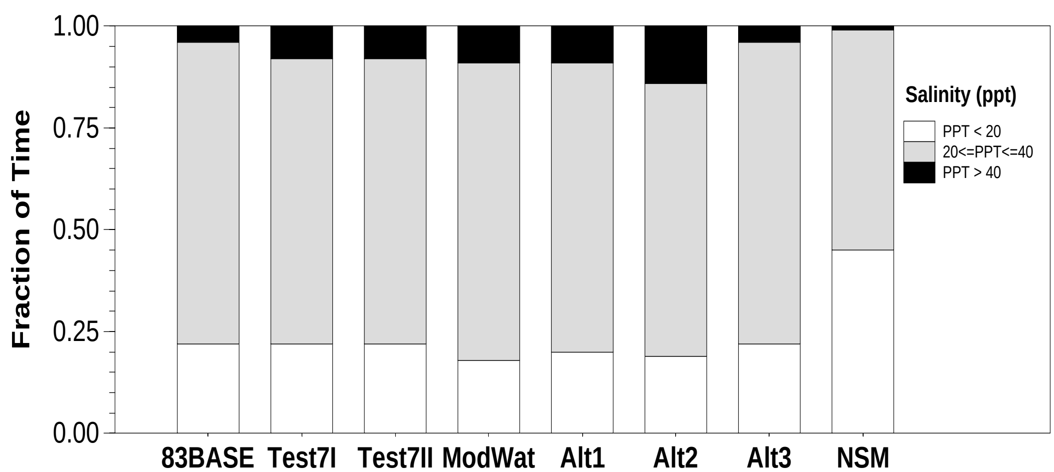


Figure 55: Salinity estimate for Little Madeira Bay based upon P33 stages.

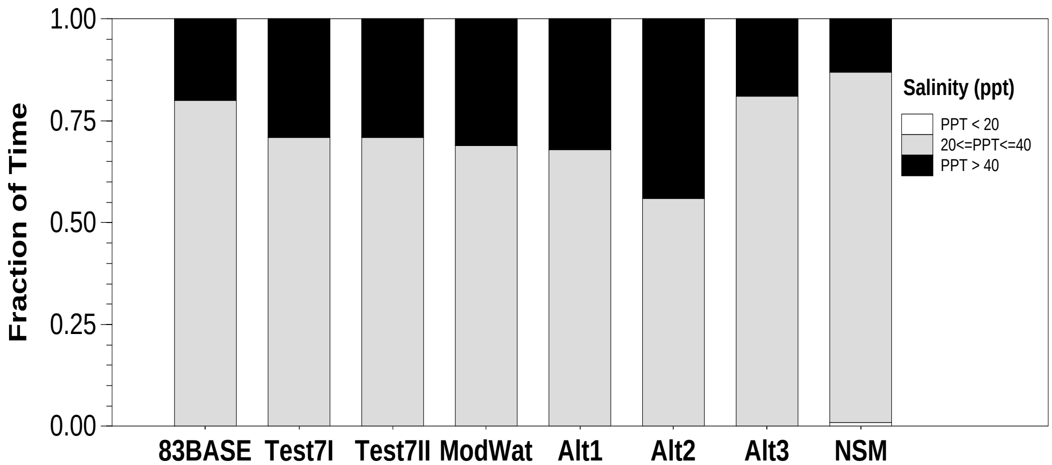


Figure 56: Salinity estimate for Terrapin Bay based upon P33 stages.

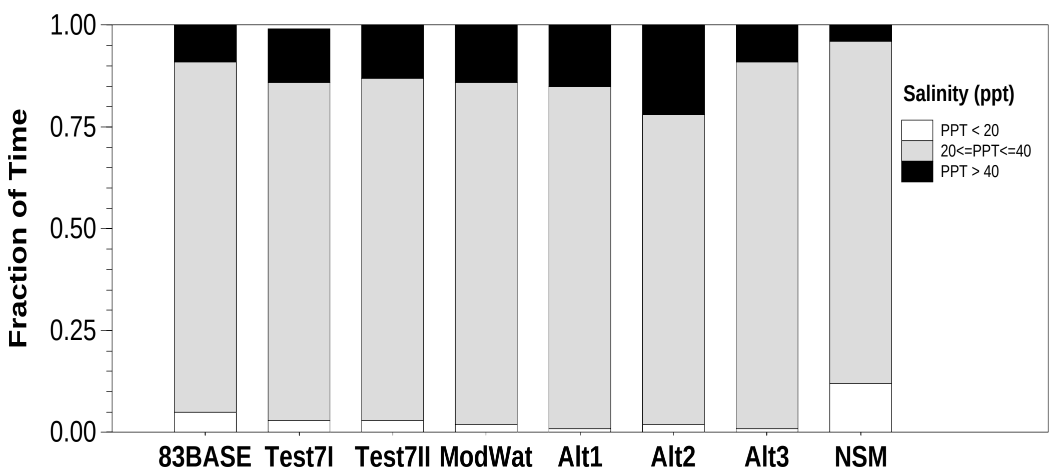


Figure 57: Salinity estimate for Garfield Bight based upon P33 stages.

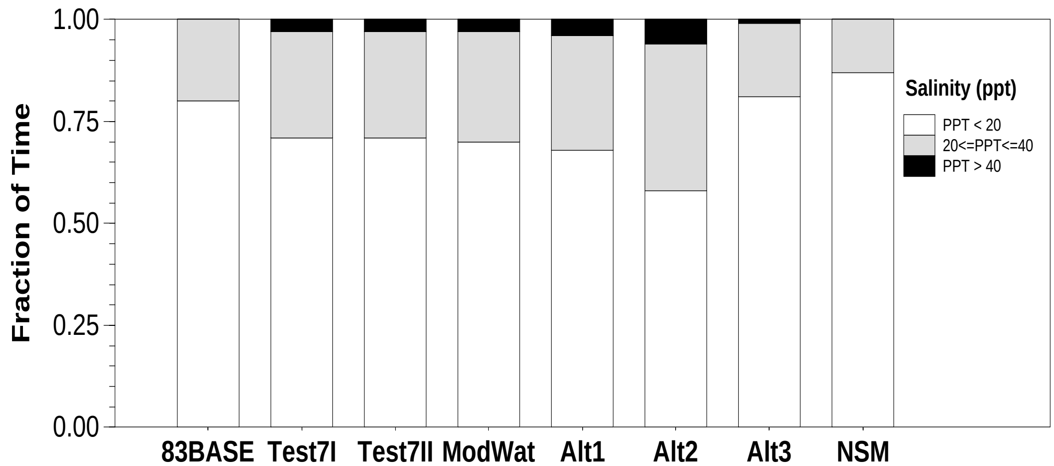


Figure 58: Salinity estimate for North River Mouth based upon P33 stages.

As the possible effects on crocodiles and manatees are related to fresh water in flows into the estuaries, it is useful to examine simulated annual flow volumes. The frequency of annual flow volumes towards Florida Bay is shown in Figure 51 (page 65). The desired condition is to provide flows that are similar to those predicted by the Natural Systems Model. According to these simulations freshwater inflows are somewhat higher into Florida Bay under Test 7 Phases I and II than under the 1983 Base Condition and NSM. According to these simulations both Test 7 Phases I and II might be expected to produce more suitable crocodile and manatee habitat than under either the 1983 Base Condition or NSM.

The information generated from these salinity estimates is somewhat contradictory to the flow estimates in Figure 51. The simulation model predicts more freshwater inflows into Florida Bay under Test 7 Phase I and II compared to the 1983 base condition, which should decrease salinities, while Figures 54–57 suggest that salinities actually increase. The apparent discrepancy is explained by the fact that the salinity predictors are based upon gage P33, located in Shark Slough, and are not directly and causally related to flows in Taylor Slough. Test 7 resulted in slightly lower P33 stages, hence the predictors estimate a regional decrease in freshwater to estuaries. This is not the case. Therefore, in estimating the effects on crocodiles and manatees, we would recommend basing the decision on the freshwater inflow estimates rather than the salinity predictors.

In addition to flow volume it is useful to look at the monthly distribution of flows towards the estuarine crocodile and manatee habitat of northeastern Florida Bay especially during the initial growth period for crocodile hatchlings, from August - December. Figure 59 shows

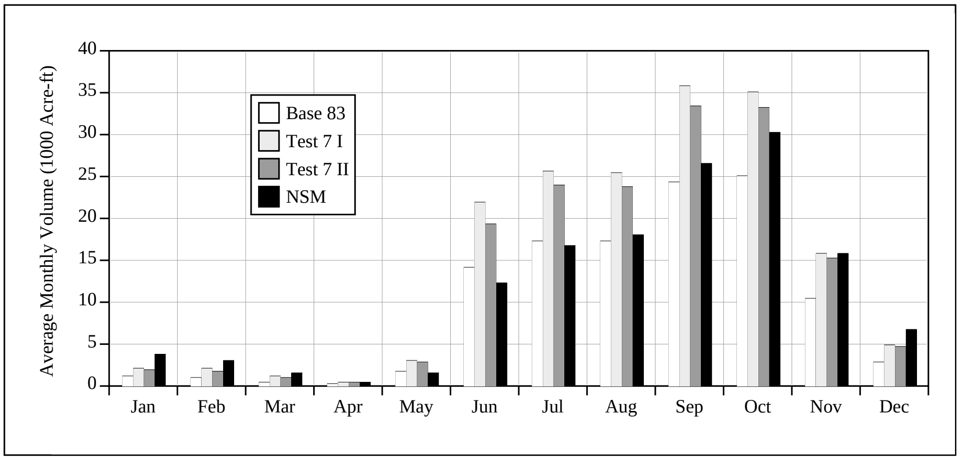


Figure 59: Average monthly flow volumes towards Florida Bay.

the distribution of mean monthly flow volumes towards Florida Bay. The desired condition is to match the pattern of monthly flow distribution as predicted by NSM. According to these simulations Test 7 Phases I and II deliver significantly more flow than NSM during the wet season and slightly less during the dry season months. NSM flow volumes are exceeded or matched during the critical hatchling survival months of August - November. Monthly flow volumes under 1983 Base Conditions equal or slightly exceed NSM flows in the early wet season, but fall significantly short of NSM during the late wet and dry seasons. These reduced flows during the fall months suggest that the 83 Base Conditions might be expected to produce less suitable crocodile habitat than under both Test 7 Phases I and II, and NSM.

Considerable attention has been focused on the potential for higher water levels resulting from upstream water discharges to flood crocodile nests especially those located along creeks. According to Mazzotti and Brandt [1989], the catastrophic flooding events that kill embryos are more closely associated with rainfall, although the frequency of those events may be increased by higher water levels. However, the proportion of creek nests appears to be declining, meaning that fewer nests are vulnerable to flooding. Mazzotti (pers. com 1994) suggests that higher water levels may be causing relocation rather than failure of nests. Increased freshwater flows into Florida Bay is expected to increase growth and survival of hatchling crocodiles. Mazzotti [1996] suggests that it is possible that an increase in survival of hatchling crocodiles could more than compensate for any loss of successful nests (high water related or not). However, there are little field data to support this hypothesis. In addition to monitoring nesting effort, distribution, and success, Mazzotti [1996] proposes

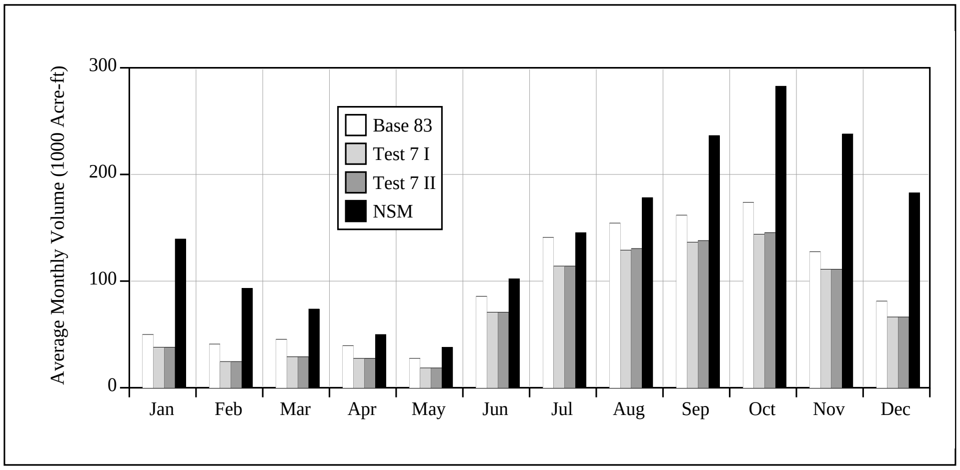


Figure 60: Average monthly flow volumes into Shark Slough.

that monitoring growth and survival of hatchling crocodiles, and the distribution of all size classes of crocs would be a more sensitive measure of population response to experimental water deliveries. Growth and survival monitoring should be included as an appropriate action in any water management alternative considered.

Historically crocodiles have been mentioned as occurring in areas as far west as Cape Sable and in recent years there has been an increase in sightings of crocodiles in the estuaries of western Everglades National Park, as well as nesting on Cape Sable [Mazzotti, 1983; pers. com 1998]. These occurrences may be due, in part, to more favorable salinity ranges and dispersal induced as a result of recent high water years. As with crocodiles in northeastern Florida Bay, the crocodile population in western ENP would be affected by freshwater inflows into the Shark Slough estuaries. Figure 52 shows the frequency of input of annual flow volumes into Shark Slough estuaries. The freshwater inflows under Test 7 Phases I and II are lower than under the 1983 Base Condition, and significantly lower than NSM. According to these simulations both Test 7 Phases I and II might be expected to produce less suitable crocodile and manatee habitat in the western Everglades estuaries than under the 1983 Base Condition, and much less than NSM.

Figure 58 shows the Crocodile Habitat Suitability graph for the North River Mouth. As with the basins of northeastern Florida Bay, the desired condition is to increase the percent of months in the low salinity category and reduce the percent of months in the high salinity category. According to these simulations Test 7 Phases I and II increase the percent of months in the high salinity category and reduce the percent of months in the lower salinity category compared to the 1983 Base Condition. According to these simulations, both Test 7 Phases I and II produce less suitable crocodile and manatee habitat than under the 1983 Base Condition. Figure 60 shows the distribution of mean monthly flow volumes into Shark Slough. As with northeastern Florida Bay, the desired condition is to match the pattern of monthly flow distribution as predicted by NSM. According to these simulations Test 7 Phases I and II, and the 83 Base Condition, share a similar pattern of monthly flow volumes that is significantly different than that predicted by NSM. The Experimental Water Deliveries Program and the 1983 Base Condition produce flows that are slightly less than NSM during the early wet season but with a pattern of increasing flows briefly similar to NSM. However, during the critical crocodile hatchling survival months of September–December and during the dry season, flow volumes fall significantly short of NSM. Flows under NSM rise sharply during the critical crocodile hatchling survival months of August–October. A steady increase in favorable salinity ranges for crocodile hatchlings would be expected. Flows under the 83 Base and the EWD for these months are nearly flat. During the dry season, flows under Phase I and II, and the 83 Base, are also nearly flat and do not show any evidence of the lag flows characteristic of the natural system. These reduced flows during the fall months, that appear to peak earlier and at significantly lower volumes than NSM, suggest that the Experimental Water Deliveries Program and the 83 Base Conditions might be expected to produce much less suitable crocodile habitat than NSM. Figure 60 also illustrates that the EWD Program does not provide any improvement, compared to the 83 Base Condition, in the pattern of flow volumes to the Shark Slough estuaries that might be considered favorable to crocodiles.

Summary

In northeastern Florida Bay, the results of the hydrologic measures used to assess effects on crocodiles and manatees appear to contradict one another.

The monthly distribution of flows towards northeastern Florida Bay is also predicted to be greater than 83 Base in all months under the Experimental Water Deliveries Program, significantly so during the critical crocodile hatchling survival months of August–December.

The crocodile habitat suitability measure is suspect in this evaluation probably due to its reliance on the gauge NP-33. This gauge is more of a regional index and is not physically or causally related to the basins of northeastern Florida Bay.

If the crocodile habitat suitability measure is rejected for use in northeastern Florida Bay and only flow volumes and their monthly distribution are considered than the following conclusion might be made: simulations suggest that the Experimental Water Deliveries Program increases favorable habitat for crocodile and manatees in northeastern Florida Bay compared to the 83 Base. However, it should be noted that under the current distribution of flows most suitable crocodile habitat occurs closer to the C-111 drainage area than Taylor Slough. Flows directed through Taylor Slough can potentially provide more and better crocodile habitat.

Both the crocodile habitat suitability measure for North River Mouth and total annual flow volumes into Shark Slough estuaries suggest less suitable habitat for crocodiles and manatees under the Experimental Water Deliveries Program than compared to 83 Base Conditions.

The monthly distribution of flows towards Shark Slough estuaries is predicted to be less than the 83 Base in all months under the Experimental Water Deliveries Program, including the critical crocodile hatchling survival months of August–December.

Accepting both the crocodile habitat suitability measure for North River Mouth and Shark Slough flow volume and monthly distribution, then the following conclusion might be made: simulations suggest that the Experimental Water Deliveries Program decreases favorable habitat for crocodiles and manatees in the Shark Slough estuaries compared to the 83 Base.

2.3.4 Snail Kite

To assess the possible effects of the Experimental Water Deliveries Program on snail kites the following geographic areas were examined: SW Shark Slough (IR 9), Mid-Shark Slough (IR 10), Northeast Shark Slough (IR 11), South WCA-3A (IR 14), West WCA-3B (IR 15), East WCA-3B (16), the western side of WCA-3A, and the extreme southern end of WCA-3A (see Figure 48 on page 62). The following hydrologic conditions relevant to the snail kite were examined for NSM, 83 Base, and existing conditions (as represented by Test 7 Phase I): hydroperiod frequencies, annual minimum ponding depth, annual 30-day minimum ponding depth, and the frequency and duration of dry-outs occurring between January and April. Tables 5 to12 summarize the selected hydrologic measures related to the snail kite for each of the geographic areas evaluated. Values that are bold are outside the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A Snail Kite Habitat Basin, Southern 3A Snail Kite Habitat Basin, and Basin - 14 Southern WCA-3A. These basins represent the major wetlands currently used by nesting kites within the area most affected by the Experimental Water Deliveries Project. Therefore, values in bold represent unfavorable conditions for snail kites.

According to this evaluation method, Tables 5 to12 suggest that under NSM generally favorable conditions for snail kites are predicted in all but the Western 3A Snail Kite Habitat Basin. Under the 83 Base, conditions for the snail kite appear to worsen considerably in Northeast Shark Slough and Eastern WCA-3B compared to NSM, yet conditions become more favorable in Western WCA-3A. In Basin 14 and the Southern 3A Snail Kite Basin conditions under the 83 Base remain favorable or improve compared to NSM. According to this particular evaluation under Test 7 Phase I conditions for snail kites remain favorable and largely unchanged in Basin 14 and the Southern 3A Snail Kite Habitat Basin compared to the 83 Base, and conditions appear to improve slightly under Test 7 in Western 3A and Western 3B. In the remaining areas, from Eastern 3B southward to SW Shark Slough, conditions under Test 7 remain generally unfavorable or worsen compared to the 83 Base.

Also used in the evaluation is the information presented in Table 13, which is a summary by basin of the fraction of years there is a drying event at or below ground surface classified as suitable conditions, marginal conditions, or unsuitable conditions for snail kites. The suitability classes are derived from Bennetts (pers. com. 1998) and Bennetts *et al.* [1998]. The classes represent relative habitat quality in relation to the time since a drying event. Suitable conditions are considered to be when drying events occur at a return frequency between 1 in 3 to 1 in 5 years. If drying events occur too frequently, greater than 1 in 2 years, the apple snail population will not have recovered to its full potential and so conditions are classified as unsuitable. If drying events occur at longer intervals, less than 1 in 6 years, then a cumulative process of habitat degradation will occur as plant communities change. This return frequency is also classified as unsuitable. Return frequencies of 1 in 2 to 1 in 3 years, and 1 in 5 to 1 in 6 years are classified as marginal.

Looking only at the frequency of drying events, Table 13 suggests that under NSM only mid-Shark Slough and SW Shark Slough are expected to provide suitable or marginal conditions for snail kites. The remaining areas are predicted to either dry out too often or not enough. Under the 83 Base, conditions for the snail kite appear to improve in several of the basins examined when compared to NSM. In all but Western 3A snail kite habitat, Eastern WCA-3B and Northeast Shark Slough are conditions marginal or suitable for snail kites under the 83 Base. According to this particular evaluation under Test 7 Phase I conditions for snail kites remain suitable or marginal and generally unchanged in the Southern 3A Snail Kite Habitat and improve in Western 3B compared to 83 Base. Elsewhere under Test 7 conditions are considered unsuitable because drying events occur too frequently. The conditions in these areas, Western 3A and from Eastern 3B southward to SW Shark Slough, are either similar to those predicted for the 83 Base or slightly worse. Overall, considering the two evaluation methods, it appears that in general Test 7 of the Experimental Water Deliveries Program either not significantly change hydrological conditions in habitats used by nesting kites.

Tables 5–13 are summary tables of hydrologic conditions in WCA-3A and WCA-3B with respect to the snail kite habitats shown in Figure 48. These summaries were generated from the graphical information presented in Appendix A. Hydroperiod summarizations were generated from Figures 142–164 depicting the frequency of occurrence of annual discontinous hydroperiod. Figures 151– 156 show the frequency of occurrence of the 30-day continuous minimum ponded water level. Figures 157– 164 show the frequency of the 1-day minimum ponded levels.

2.4 Conclusions on Effects of Test 7 on Endangered Species

With respect to the Cape Sable seaside sparrow, we have the following conclusions:

- The Experimental Water Deliveries Program Tests 3 through 7 have not had any significant beneficial effect on the western Cape Sable sparrow subpopulation (subpopulation A). Both the current and Experimental Water Deliveries hydrologic regimes are fundamentally the same with respect to the western subpopulation.

- According to Pimm [1997], if current hydrologic regimes are continued, the western subpopulation will probably become locally extinct, placing the species at an unacceptable risk of extinction.

- The Experimental Water Deliveries Program has had no appreciable effect on the Ingraham Highway sparrow subpopulation (subpopulation B).

Western WCA-3A Snail Kite Habitat				
Indicator	NSM	1983 Base	Test 7 Phase I	Test 7 Phase II
Median Hydroperiod (days/year)	**358**	365	360	360
Fraction of years hydroperiod less than 310 days	**0.39**	**0.35**	**0.35**	**0.35**
Fraction of years there is a drying event	**0.63**	0.55	**0.61**	0.58
Fraction of years there is a drying event lasting 30 days or longer	0.42	**0.45**	0.42	0.42
Fraction of years there is a drying event before May	0.55	0.54	**0.55**	0.55

Table 5: Summary of selected measures related to the snail kite for the Western 3A Snail Kite Habitat. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Southern WCA-3A Snail Kite Habitat				
Indicator	NSM	1983 Base	Test 7 Phase I	Test 7 Phase II
Median Hydroperiod (days/year)	365	365	365	365
Fraction of years hydroperiod less than 310 days	0.28	**0.07**	0.10	0.10
Fraction of years there is a drying event	0.53	0.34	0.33	0.34
Fraction of years there is a drying event lasting 30 days or longer	0.35	0.19	0.19	0.16
Fraction of years there is a drying event before May	0.49	0.18	0.18	0.18

Table 6: Summary of selected measures related to the snail kite for southern Snail Kite habitat. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 14: Southern WCA-3A				
Indicator	NSM	1983 Base	Test 7 Phase I	Test 7 Phase II
Median Hydroperiod (days/year)	365	365	365	365
Fraction of years hydroperiod less than 310 days	0.32	**0.07**	0.07	0.07
Fraction of years there is a drying event	0.51	0.26	**0.23**	**0.23**
Fraction of years there is a drying event lasting 30 days or longer	0.39	**0.10**	**0.10**	**0.10**
Fraction of years there is a drying event before May	0.48	**0.09**	**0.11**	**0.10**

Table 7: Summary of selected measures related to the snail kite for Indicator Region 14: Southern WCA-3A. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 15: Western WCA-3B				
Indicator	NSM	1983 Base	Test 7 Phase I	Test 7 Phase II
Median Hydroperiod (days/year)	**359**	365	365	365
Fraction of years hydroperiod less than 310 days	0.30	0.33	0.23	0.27
Fraction of years there is a drying event	0.58	0.44	0.40	0.41
Fraction of years there is a drying event lasting 30 days or longer	0.39	0.35	0.35	0.35
Fraction of years there is a drying event before May	0.52	0.35	0.30	0.30

Table 8: Summary of selected measures related to the snail kite for Indicator Region 15- West WCA-3B. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 16: Eastern WCA-3B				
Indicator	NSM	1983 Base	Test 7 Phase I	Test 7 Phase II
Median Hydroperiod (days/year)	365	**272**	**300**	**299**
Fraction of years hydroperiod less than 310 days	0.19	**0.71**	**0.59**	**0.59**
Fraction of years there is a drying event	0.50	**0.92**	**0.80**	**0.81**
Fraction of years there is a drying event lasting 30 days or longer	0.32	**0.81**	**0.65**	**0.65**
Fraction of years there is a drying event before May	0.40	**0.79**	**0.65**	**0.66**

Table 9: Summary of selected measures related to the snail kite for Indicator Region 16- East WCA-3B. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 11: Northeast Shark Slough				
Indicator	NSM	1983 Base	Test 7 Phase I	Test 7 Phase II
Median Hydroperiod (days/year)	365	**277**	**352**	**353**
Fraction of years hydroperiod less than 310 days	**0.06**	**0.74**	**0.39**	**0.41**
Fraction of years there is a drying event	**0.14**	**0.95**	0.58	0.59
Fraction of years there is a drying event lasting 30 days or longer	**0.10**	**0.81**	**0.48**	**0.48**
Fraction of years there is a drying event before May	**0.03**	**0.88**	**0.56**	**0.56**

Table 10: Summary of selected measures related to the snail kite for Indicator Region 11- Northeast Shark Slough. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 10: Mid Shark Slough				
Indicator	NSM	1983 Base	Test 7 Phase I	Test 7 Phase II
Median Hydroperiod (days/year)	365	365	363	365
Fraction of years hydroperiod less than 310 days	**0.06**	0.14	0.32	0.32
Fraction of years there is a drying event	**0.19**	0.45	0.55	0.55
Fraction of years there is a drying event lasting 30 days or longer	**0.10**	0.32	0.42	0.42
Fraction of years there is a drying event before May	**0.03**	0.29	0.45	0.42

Table 11: Summary of selected measures related to the snail kite for Indicator Region 10- Mid- Shark Slough. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 9: SW Shark Slough				
Indicator	NSM	1983 Base	Test 7 Phase I	Test 7 Phase II
Median Hydroperiod (days/year)	365	365	**357**	**358**
Fraction of years hydroperiod less than 310 days	0.09	0.25	**0.37**	**0.37**
Fraction of years there is a drying event	0.25	0.47	0.60	0.60
Fraction of years there is a drying event lasting 30 days or longer	0.13	0.39	**0.48**	**0.48**
Fraction of years there is a drying event before May	0.14	0.40	**0.56**	**0.56**

Table 12: Summary of selected measures related to the snail kite for Indicator Region 9- SW Shark Slough. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Basin	NSM	83 Base	Test 7 Phase I	Test 7 Phase II
Western 3A Snail Kite Habitat	0.63	0.55	0.61	0.58
IR 14- Southern WCA-3A	0.51	**0.26**	**0.23**	**0.23**
Southern 3A Snail Kite Habitat	0.53	*0.34*	**0.33**	*0.34*
IR 15-West WCA-3B	0.58	*0.44*	*0.40*	*0.40*
IR 16-East WCA-3B	0.50	0.92	0.80	0.81
IR 11-Northeast Shark Slough	0.14	0.95	0.58	0.59
IR 10-Mid-Shark Slough	*0.19*	*0.45*	0.55	0.55
IR 9- SW Shark Slough	**0.21**	*0.47*	0.60	0.60

Suitability Legend		
Condition	Range[a]	Type font
Unsuitable	$f <= 0.16$	Roman
Marginal	$0.16 < f <= 0.19$	*Italic*
Suitable	$0.20 < f <= 0.33$	**Bold**
Marginal	$0.33 < f <= 0.49$	*Italic*
Unsuitable	$f > 0.49$	Roman

[a] Where f is the exceedence frequency of a dryout.

Table 13: Summary by basin of the fraction of years there is a drying event at or below ground surface, classified as suitable, marginal, or unsuitable.

- The Experimental Water Deliveries Program has had adverse hydrologic effects on the habitats supporting subpopulations D and F. Lowering of L-31N levels has resulted in overdrainage in the the northern areas (subpopulation F), and flooding in the southern areas (subpopulation D).
- Phase II of Test Iteration 7 represents an improvement relative to Phase I for subpopulations D, E, and F. The Base 1983 Condition is better relative to either Test 7 Phase I or Test 7 Phase II for subpopulation F; Base 1983 and Test 7 Phase II are the same for subpopulation E.
- The effects of the Experimental Water Deliveries Program Test Iteration 7 are not clear for subpopulation C, nearest L-31W. Further, more detailed analyses are recommended.

With respect to the wood stork, we have the following conclusions:

- The Experimental Water Deliveries Program is predicted to have worsened, wood stork foraging habitat conditions in the region of the traditional Shark Slough estuarine stork nesting colonies, compared to the 83 Base Conditions.
- When Shark Slough and Taylor Slough are considered together the combined scores suggest that overall the Experimental Water Deliveries Program provides wood stork foraging habitat conditions that match or slightly exceed that predicted under 83 Base Conditions.
- The combined total scores are significantly affected by the large increases predicted for Taylor Slough flows (118 - 126%) under Experimental Water Deliveries. However, it should be noted that the current distribution of flows is skewed to the east, closer to the C-111 drainage area than to Taylor Slough. It is probable that flows directed through Taylor Slough can potentially provide more and better wood stork habitat. However, it should not be assumed that a flow for Taylor Slough that averages well above NSM is beneficial for storks. It may be just as detrimental, ecologically, as a below average flow in Shark Slough (Ogden, pers. comm.)

With respect to the crocodile and manatee, we have the following conclusions:

- In northeastern Florida Bay, the results of the hydrologic measures used to assess effects on crocodiles and manatees appear to contradict one another.

- The monthly distribution of flows into northeastern Florida Bay is also predicted to be greater than 83 Base in all months under the Experimental Water Deliveries Program, significantly so during the critical crocodile hatchling survival months of August - December.
- The crocodile habitat suitability measure is suspect in this evaluation probably due to its reliance on the gauge NP-33. This gauge is more of a regional index and is not physically or causally related to the basins of northeastern Florida Bay.
- If the crocodile habitat suitability measure is rejected for use in northeastern Florida Bay and only flow volumes and their monthly distribution are considered than the following conclusion might be made: simulations suggest that the Experimental Water Deliveries Program increases favorable habitat for crocodile and manatees in northeastern Florida Bay compared to the 83 Base. However, it should be noted that under the current distribution of flows most suitable crocodile habitat occurs closer to the C-111 drainage area than Taylor Slough. Flows directed through Taylor Slough can potentially provide more and better crocodile habitat.
- Both the crocodile habitat suitability measure for North River Mouth and total annual flow volumes into Shark Slough estuaries suggest less suitable habitat for crocodiles and manatees under the Experimental Water Deliveries Program than compared to 83 Base Conditions.
- The monthly distribution of flows into Shark Slough estuaries is predicted to be less than the 83 Base in all months under the Experimental Water Deliveries Program, including the critical crocodile hatchling survival months of August - December.
- Accepting both the crocodile habitat suitability measure for North River Mouth and Shark Slough flow volume and monthly distribution, then the following conclusion might be made: simulations suggest that the Experimental Water Deliveries Program decreases favorable habitat for crocodiles and manatees in the Shark Slough estuaries compared to the 83 Base.

With respect to the snail kite, we have the following conclusion:

- Overall, considering the two evaluation methods, it appears that in general Test 7 of the Experimental Water Deliveries Program does not significantly change hydrological conditions in habitats used by nesting kites.

Chapter 3

Alternatives for Experimental Water Deliveries

In order to address the shortcomings of the Experimental Water Deliveries Program, we examined three alternative test iterations. The objective in these alternatives was not to devise the comprehensive plan which meets all water resources management and ecosystem management objectives. Rather, we focused on determining the magnitude of operational changes required for a significant improvement for Shark Slough.

Because of the severe time constraints, we decided to limit the number of alternatives examined to three. Thus, we fully expect that these alternatives can be improved and refined, but they should give some substantive information on directions which would improve conditions in Shark Slough. Table 14 summarizes the most important characteristics of the alternatives. More detailed descriptions of the canal stage settings are found in Table 15.

The three alternatives where chosen in the following way. The first alternative was intended to examine the effects of implementing many of the operational and structural plans currently under discussion, but not fundamentally altering the Rainfall Plan or the WCA-3A schedule (Figure 4). The next two alternatives were tests of plans the South Florida Water Management District has been investigating as part of the Lower East Coast Water Supply Planning Process [South Florida Water Management District, 1998]. The second alternative as a plan that attempted to reproduce, in a limited way, flow patterns

Component	Test 7 Phase I	Alternative 1	Alternative 2	Alternative 3
Shark Slough	Rainfall Plan	Rainfall Plan	NSM Flow	NSM Stage
L-67ext	Intact	Removed	Removed	Removed
L-29	7.5 ft max	8.0 ft max	8.0 ft max	8.0 ft max
S-355	Not used	Priority for NESS flows	Priority for NESS flows	Not Used
S-331	Angel's well criteria	Angel's well criteria	Angel's well criteria	Angel's well criteria
8.5 SMA	No levee	No levee	Levee	Levee

Table 14: Summary of differences in Experimental Water Deliveries alternatives evaluated in this analysis.

through WCA-3B and Northeast Shark Slough, and using flow targets predicated on the Natural Systems Model. The third alternative was a very limited form of the recommended plan from the South Florida Water Management District's *Interim Plan for the Lower East Coast Water Supply*, *Alt5-Phase I*. The plan calls for management of flows to Everglades National Park based upon water level targets from the Natural Systems Model. We looked at a limited form of this plan primarily because the Experimental Water Deliveries Program, the subject of the consultation, deals only with flows to Everglades National Park and is not a regional operational program. However, a regional implementation of such a plan would likely result in more widespread ecological benefits.

3.1 Model Description

Tables 15 and 16 are detailed descriptions of operational levels and plans for each of the three alternatives considered here. Parameters not listed in these tables were taken as the same as the 1983 Base Condition.

The purpose of this analysis is not a detailed investigation of the overall hydrologic effects of these alternatives. Rather, the primary focus is on determining what the potential impacts of these alternatives are for endangered species. We expect that, upon identification of some acceptable plan, more detailed hydrologic analysis will be required. Therefore, the only hydrologic analysis included here is specifically related to endangered species.

3.2 Effects on Endangered Species

3.2.1 Cape Sable sparrow

The analysis of the effects of the investigated alternatives begins by again looking how the hydrologic modifications affect the sparrow's nesting opportunity. Figures 61–72 are measures of the number of consecutive days that water levels are below land surface.

The most important results of the simulations are Figures 61 and 67, which shows that the number of nesting days increases for Alternative 3 during the above average rainfall years. Note that Alternative 1, which keeps the Rainfall Plan and WCA-3A Regulation Schedule intact, is not uniformly better than Test 7 Phase I. That is, without changes

Canal Name	Structure Name	Alternative 1 Open	Alternative 1 Close	Alternative 2 Open	Alternative 2 Close	Alternative 3 Open	Alternative 3 Close
L-31N	G-211	6.0	5.5	6.0	5.5	6.0	5.5
L-31N	S-331	Angel's Well[a] Criteria		Angel's Well Criteria		Angel's Well Criteria	
L-31N	S-194	5.7	5.3(5.2)	5.7	5.3(5.2)	5.7	5.3(5.2)
L-31N	S-196	5.7	5.3	5.7	5.3(5.2)	5.7	5.3(5.2)
L-31N	S-174	See S-332D[b]		See S-332D		See S-332D	
L-31N	S-176	5.2	5.0	5.3	5.1	5.4	5.2
L-31N	S-332D	5.0 RDP for WCA-3A No max TW stage	4.8	5.25 RDP for L-31W No max TW stage	5.0	5.3 RDP for L-31W No max TW stage	5.0
WCA-3A	S-332	Not Used		Not Used		Not Used	
WCA-3A	S-175	Not Used		Not Used		Not Used	
C-111	S-177	5.2	4.3	4.9	4.3	5.2	4.3
C-111	S-18C	2.4	1.6	2.6	2.3	2.6	2.3
C-111	S-197	S-197[c] Criteria		S-197 Criteria		S-197 Criteria	
C-1W	S-148	5.2	4.8	5.2	4.8	5.2	4.8
C-103	S-167	5.0	4.3	5.0	5.3	5.0	4.3
C-103	S-179	5.0	4.3	5.0	5.3	5.0	4.3

[a] If 5.5 $<$ Angel's well $<$ 6.0, pump to maintain S-331 HW between 4.5 & 5.0; If Angel's well $>$ 6.0 pump to maintain S-331 HW between 4.0 & 4.5;Terminate pumping if S176 HW $>$ 5.5;Terminate pumping if S-331 TW $>$ 6.0; Resume pumping when S176 falls below 5.0

[b] S-174 used in addition to S-332D flows when HW $>$ TW

[c] If S-177& Either S-177HW $>$4.1 or S-18C $>$ 2.8 Open 3 Culverts;If S-177HW $>$4.2 or S-18C $>$ 3.1 Open 7 Culverts;If S-177HW $>$4.3 or S-18C $>$ 3.3 Open 13 Culverts

Table 15: Summary of operations for the southern components of the South Dade Conveyance System for the alternatives investigated.

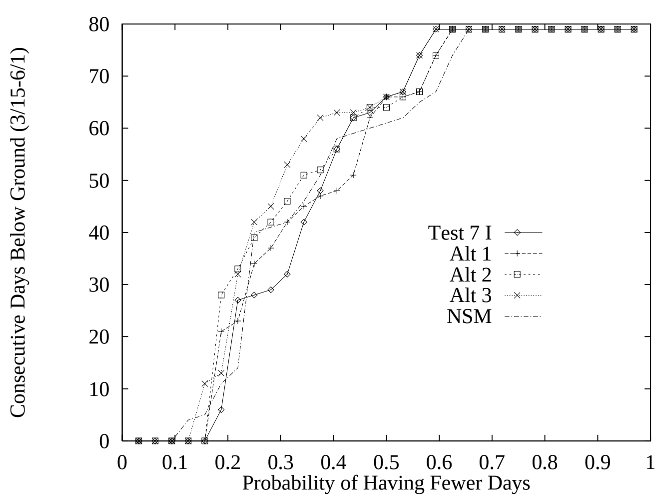


Figure 61: Return frequencies for number of consecutive days when water levels are below ground between March 15 and June 1 for sparrow habitat A.

Canal Name	Structure Name	Alternative 1 Operation	Alternative 2 Operation	Alternative 3 Operation
L-29	S-333	Rainfall Formula Close when TW > 8.0	NSM Flow Targets Close when TW > 8.0	NSM Stage Targets[a] Close when TW > 8.0
L-29	S-334	Water Supply	Water Supply	Water Supply
L-29	S-355	Operational	Operational	Not Used
L-29	S-12	Rainfall Formula [b] WCA-3A Schedule (see Fig 4)	NSM Flow Targets Pass undeliverable S-333 flows	NSM Stage Targets
L-67ext		Removed	Removed	Removed
L-67A/C		Gaps[c]	Gaps	No Gaps
L-28	S344 S343A&B	BICY Env. Option	BICY Env. Option	BICY Env. Option
8.5 SMA	Levee	Not included	Not included	Included

[a] See Alternative 5 Phase I of the Lower East Coast Water Supply Plan. Target targets activated ONLY for Northeast Shark Slough and western Shark Slough.

[b] The rainfall formula is described in Appendix A of Neidrauer and Cooper [1989]

[c] Calculated by $Q = 200\Delta H^{1.5}$ where ΔH is the head difference between WCA-3A and WCA-3B, and where $Q_{\max} = 800$ cfs.

Table 16: Summary of Operations for Water Conservation Area 3A and the northern components of the South Dade Conveyance System for the investigated alternatives.

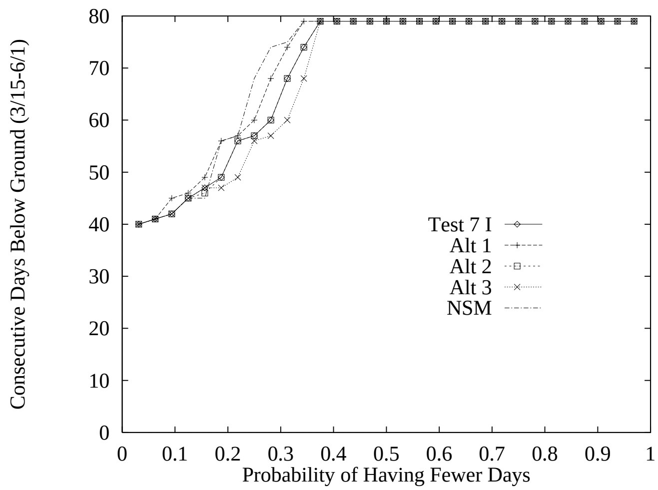


Figure 62: Return frequencies for number of consecutive days when water levels are below ground between March 15 and June 1 for sparrow habitat B.

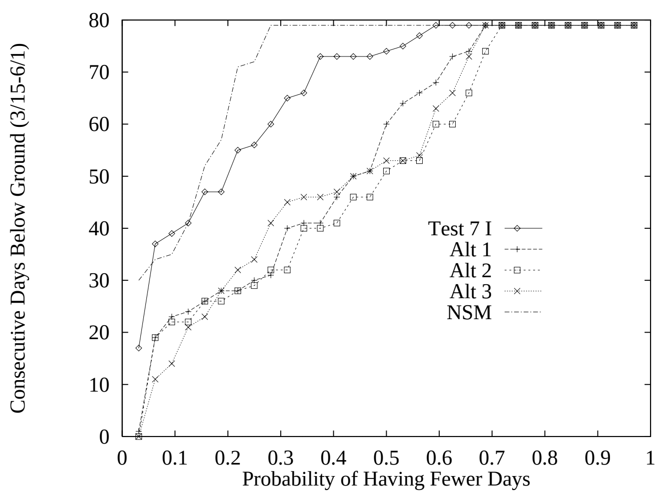


Figure 63: Return frequencies for number of consecutive days when water levels are below ground between March 15 and June 1 for sparrow habitat C.

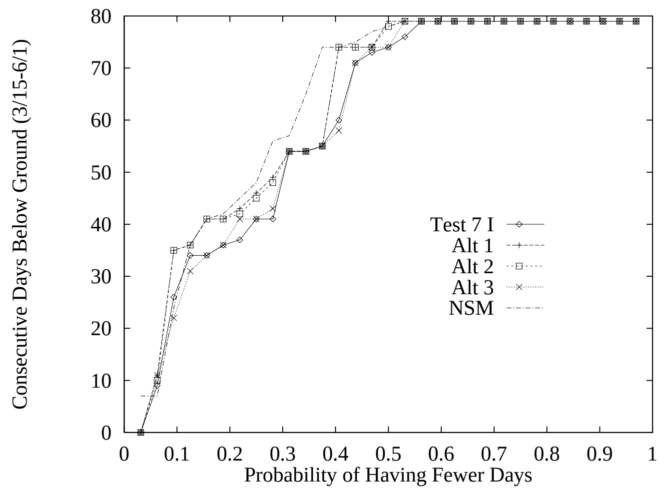


Figure 64: Return frequencies for number of consecutive days when water levels are below ground between March 15 and June 1 for sparrow habitat D.

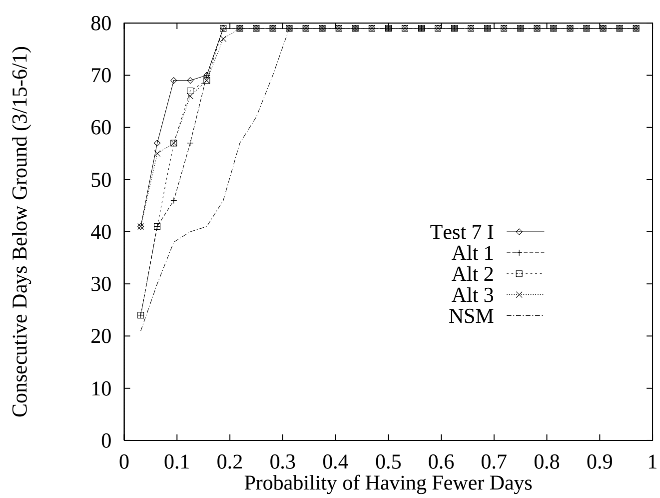


Figure 65: Return frequencies for number of consecutive days when water levels are below ground between March 15 and June 1 for sparrow habitat E.

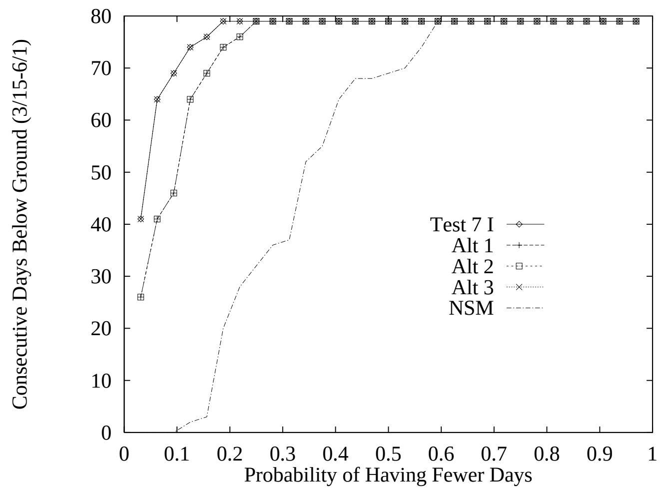


Figure 66: Return frequencies for number of consecutive days when water levels are below ground between March 15 and June 1 for sparrow habitat F.

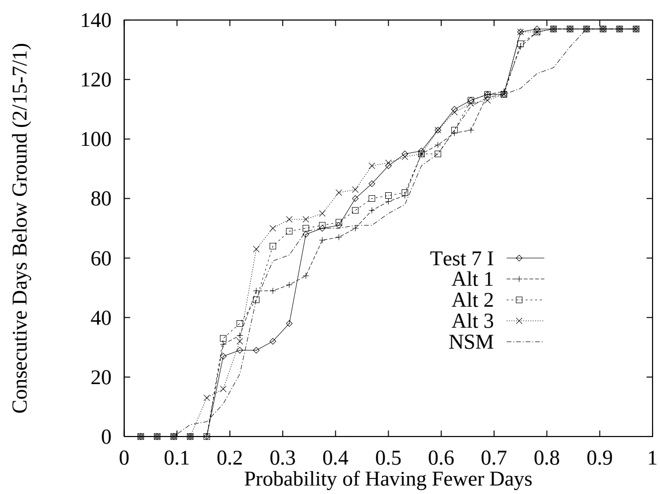


Figure 67: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat A.

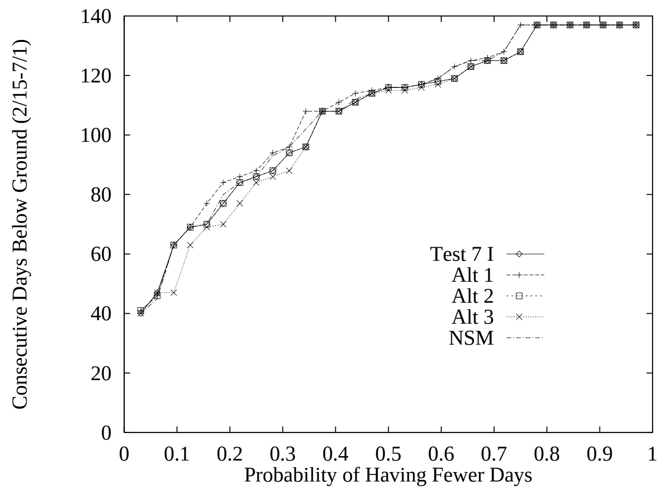


Figure 68: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat B.

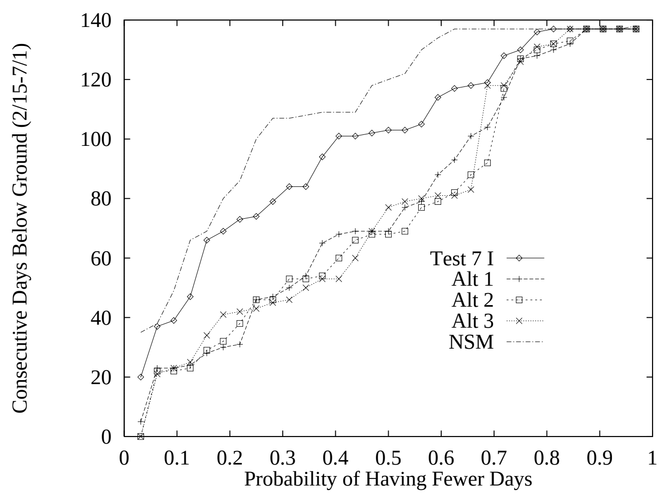


Figure 69: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat C.

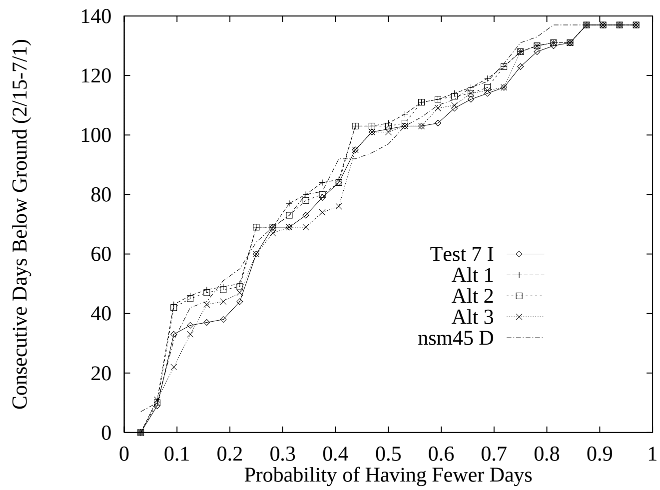


Figure 70: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat D.

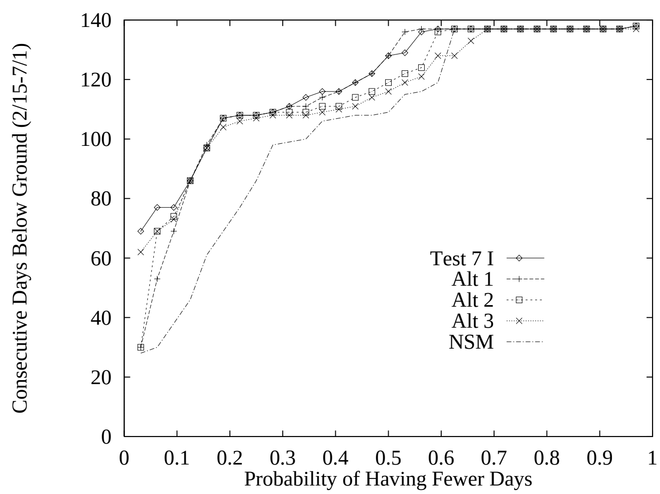


Figure 71: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat E.

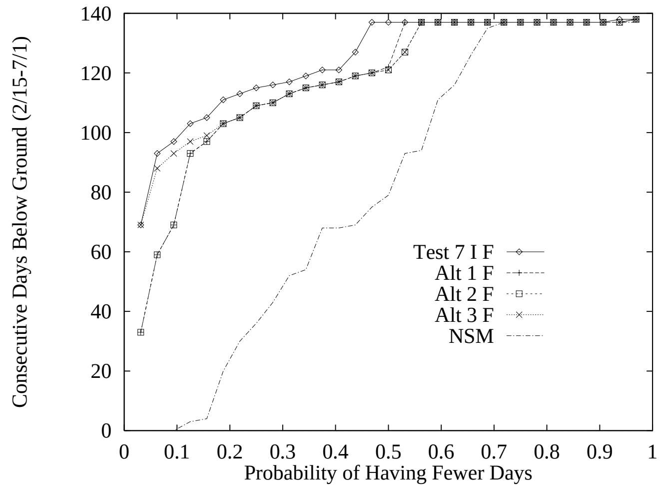


Figure 72: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat F.

to the Rainfall Plan/3A Schedule, there are mixed effects for the western subpopulation. Moreover, changing the delivery scheme which mimics the Natural Systems Model shows benefits for the western subpopulation, as well as Shark Slough overall.

Subpopulation A and D are the only subpopulations which, according to the modeling simulations, have potential restrictions to their nesting activity because of flooding. For subpopulation D, all three alternatives are somewhat improved relative to Test 7 Phase I. All alternatives employ operational rules similar to Test 7 Phase II, which performs better than Test 7 Phase I. Also, all alternatives are very similar to Natural System Model results, and all show return frequencies of between 1-year-in-10 and 1-year-in-6 for having fewer than 40 nesting days between February and July.

Subpopulation C appears to be affected by all of the proposed alternatives. In general, alternatives which supply increasing flows to Northeast Shark Slough also show decreasing nesting opportunity. The most likely explanation is that, as seepage into L-31N is increased, this flow is collected by L-31N and pumped through S-332D and into Taylor Slough. Thus, it would appear that S-332D is responding to Northeast Shark Slough inflows and adverse affects on subpopulation C may be a side effect. Again, more detailed and reliable information would be obtained from the Corps' MODBRANCH simulations.

The nesting windows for subpopulations B, E, and F do not appear to be greatly affected by any of the alternatives. However, these subpopulations are not constrained by

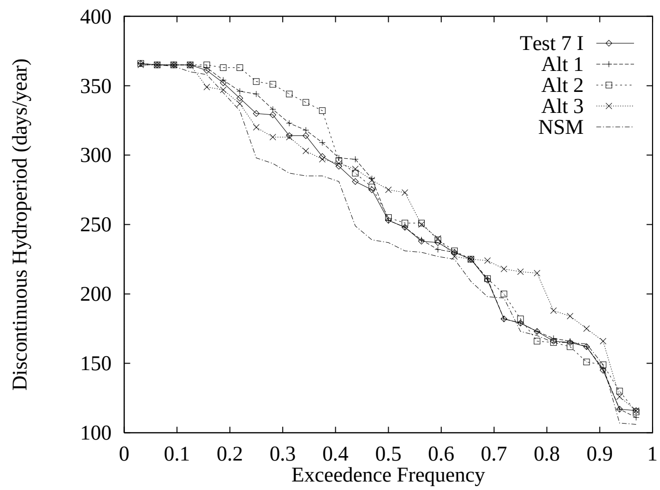


Figure 73: Hydroperiod frequencies for sparrow habitat A.

nesting opportunity. According to Pimm [1997], subpopulations E and F are affected by fire frequency, which is directly related to the hydroperiod. Figure 73–78 are measures of the number of days per year that one can expect the sparrow habitats to be flooded.

3.2.2 Wood Stork

The possible effects of the Alternatives on wood storks are estimated by applying the same performance measure as above to the simulated water management scenarios being considered and comparing the results to the 83 Base Conditions and Test 7 Phases I and II, shown in Table 17 on page 105. Table 17 also shows the results of this evaluation. According to this evaluation the three alternatives provide average uninterrupted hydroperiods that are 20 - 50% of NSM values. By basin, the simulations suggest that alternative 3 performs better than the other alternatives in mid-Shark Slough (IR 10), and better than Test 7 Phases I and II. In southwestern Shark Slough (IR 9) alternative 3 performs better than the other alternatives and Test 7, matching 83 Base Conditions. Alternatives 1 and 2 provide similar overall hydroperiods (IR Mean) compared to Test 7 Phases I and II, and fall significantly short of 83 Base Conditions. Overall alternative 3 provides modest improvement in uninterrupted hydroperiods (IR Mean) over Test 7 Phase I and II, matching 83 Base Conditions.

The simulations suggest that for average annual flow volumes into the Shark Slough

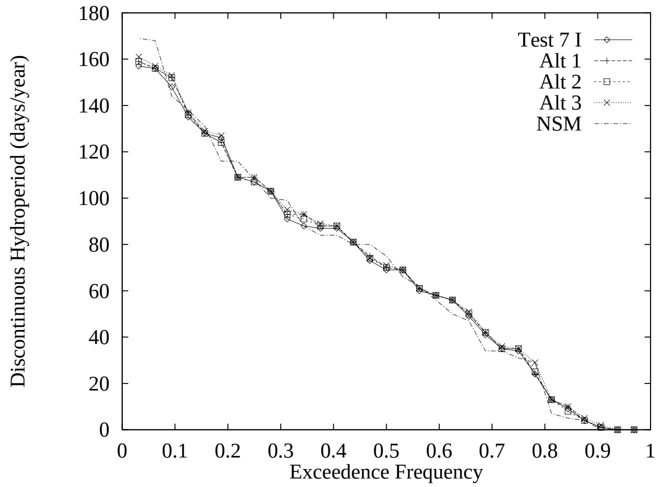


Figure 74: Hydroperiod frequencies for sparrow habitat B.

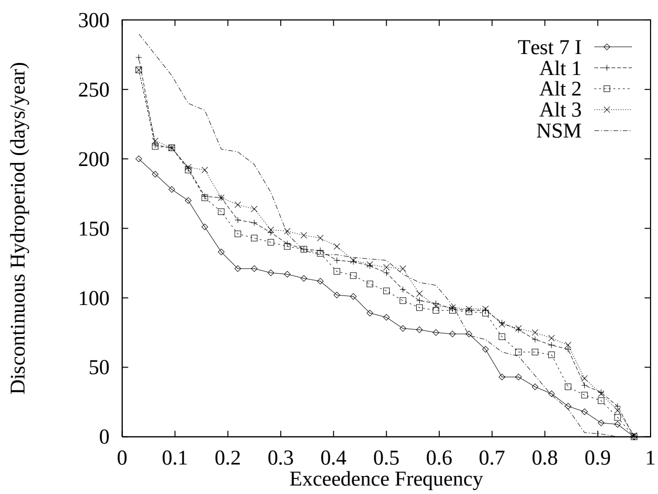


Figure 75: Hydroperiod frequencies for sparrow habitat C.

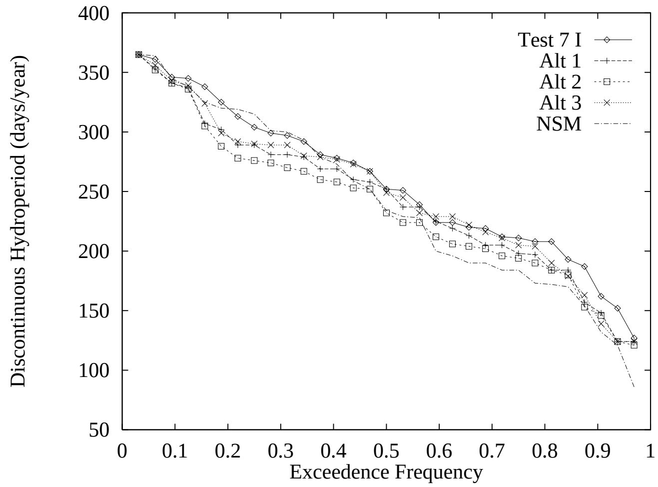


Figure 76: Hydroperiod frequencies for sparrow habitat D.

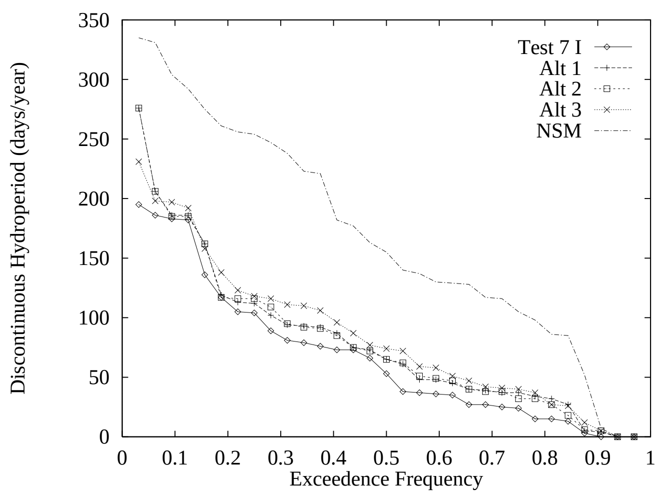


Figure 77: Hydroperiod frequencies for sparrow habitat E.

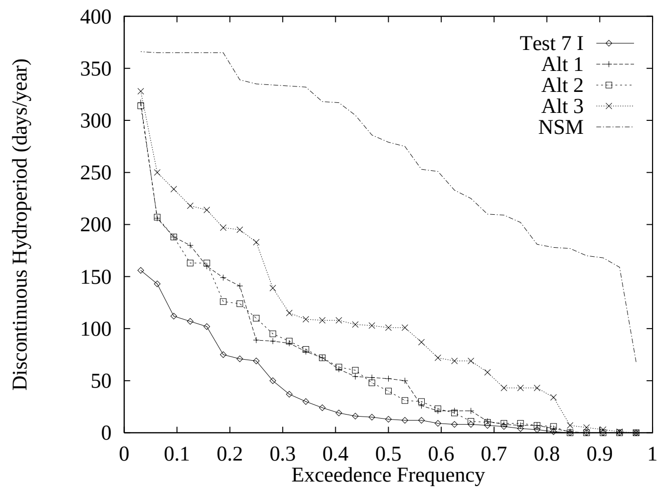


Figure 78: Hydroperiod frequencies for sparrow habitat F.

estuaries, the alternatives provide 54 - 56% of NSM values. Alternatives 1 and 2 provide a similar percentage of NSM values as Test 7 Phases I and II. For flow volumes into Shark Slough, alternative 3 provides a greater percentage of NSM values similar to the other alternatives and Test 7 Phases I and II, almost equaling the 83 Base Condition. For Taylor Slough, the three alternatives provide more than 100% of the volume of average annual NSM flows, while under the 83 Base Conditions flows are only 87% of NSM values. For flow volumes into Taylor Slough, the three alternatives perform as well as or slightly better than Test 7 Phases I and II. For flow into the estuaries (Shark Slough and Taylor Slough combined) the alternatives perform as well as or better than Test 7 Phases 1 and II, and exceed the 83 Base.

Overall, when hydroperiods and flow volumes are considered together, alternatives 1 and 2 are very similar to Test 7 Phases I and II and predicted to have no effect on wood stork foraging habitat conditions in the region of the traditional Shark Slough estuarine stork nesting colonies, compared to the current conditions. For Shark Slough, alternative 3 provides an approximately 8% improvement in habitat conditions over the Experimental Water Deliveries Program, approaching that predicted for the 83 Base. Again, as above, this measure assumes a linear relationship between hydropattern and habitat. Overall when Shark Slough and Taylor Slough are evaluated together (Total Score) alternatives 1 and 2 are again very similar to Test 7 Phases I and II and predicted to have little or no effect on wood stork foraging habitat, compared to current conditions. For Shark Slough and Taylor Slough evaluated together, alternative 3 provides the greatest improvement (19%) in habitat conditions over the 83 Base, and an 11 - 14% improvement over the Experimental

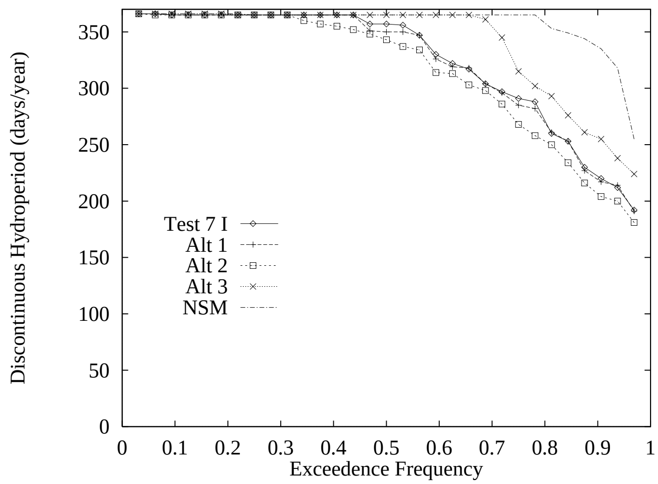


Figure 79: Exceedence Frequency for hydroperiod for SW Shark River Slough (Indicator Region 9).

Water Deliveries Program. It should be noted that the combined total scores are significantly affected by the large increases predicted for Taylor Slough flows (117 - 140%) under Experimental Water Deliveries and the alternatives.

3.2.3 Crocodile and Manatee

The Crocodile Habitat Suitability graphs for the alternatives being considered are shown in Figures 54–58 (pages 69 – 71.) As above, the desired condition is to increase the percent of months in the low salinity category and reduce the percent of months in the high salinity category. According to these simulations Alternatives 1 and 2 increase the percent of months in the high salinity category and reduce the percent of months in the lower salinity category compared to the 1983 Base Condition. The percent of months predicted in each salinity category for Alternatives 1 and 2 is similar to that predicted by Test 7 Phase I and II, with Alternative 2 generally being slightly worse. Alternative 3 produces a percentage of months in each salinity category similar to the 83 Base Condition which is an improvement over both Alternatives 1 and 2, and Test 7 Phases I and II. According to these simulations Alternative 3 might be expected to produce somewhat more suitable crocodile and manatee habitat than under the two other alternative or the Experimental Water Deliveries Program.

As noted above, the possible effects of water management alternatives on crocodiles and manatees are related to fresh water in flows towards the estuaries. Therefore, it is useful

Indicator	NSM	83 Base	Alt 1	Alt 2	Alt 3	Mod Wat [a]
IR 9 inundation[b]	161.	73.5	51.3	44.8	80.4	49.5
IR 10 inundation[c]	253.	87.1	58.7	53.7	103.	56.4
IR 9 Ratio to NSM	1.0	0.46	0.32	0.28	0.5	0.31
IR 10 Ratio to NSM	1.0	0.34	0.23	0.21	0.41	0.22
IR Mean	1.0	0.4	0.27	0.24	0.45	0.26
Taylor Slough[d]	138.	121.	194.	183.	200.	128.
Shark Slough[e]	1770.	1100.	952.	952.	990.	937.
Taylor Slough Ratio to NSM	1.0	0.87	1.4	1.3	1.4	0.93
Shark Slough Ratio to NSM	1.0	0.62	0.54	0.54	0.56	0.53
Flow Mean	1.0	0.75	0.97	0.93	1.	0.73
Total Score[f]	1.0 **(1.0)**	0.63 **(0.55)**	0.74 **(0.45)**	0.70 **(0.44)**	0.82 **(0.52)**	0.57 **(0.44)**

[a] Discussed in Section 4.3.2 on page 168
[b] Average number of weeks of continuous inundation
[c] Average number of weeks of continuous inundation
[d] Annual Flow Volume, in thousands of acre-ft
[e] Annual Flow Volume, in thousands of acre-ft
[f] Total score calculated with and (without) Taylor Slough scores. Flow volume weight multiplied by 2.

Table 17: Summary of hydrologic performance measures related to the wood stork.

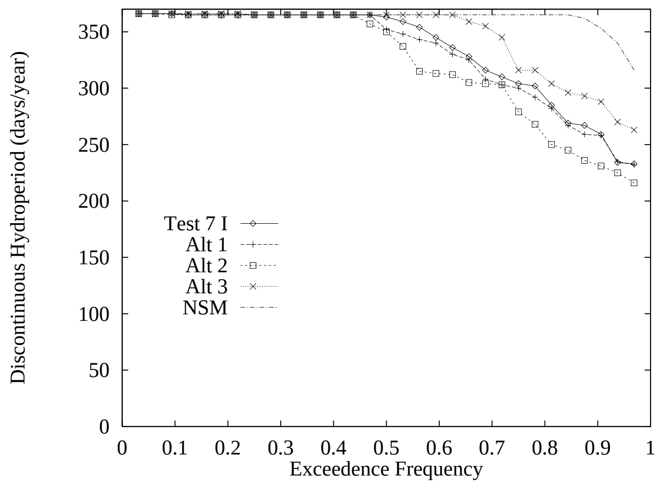


Figure 80: Exceedence Frequency for hydroperiod forMid-Shark River Slough (Indicator Region 10).

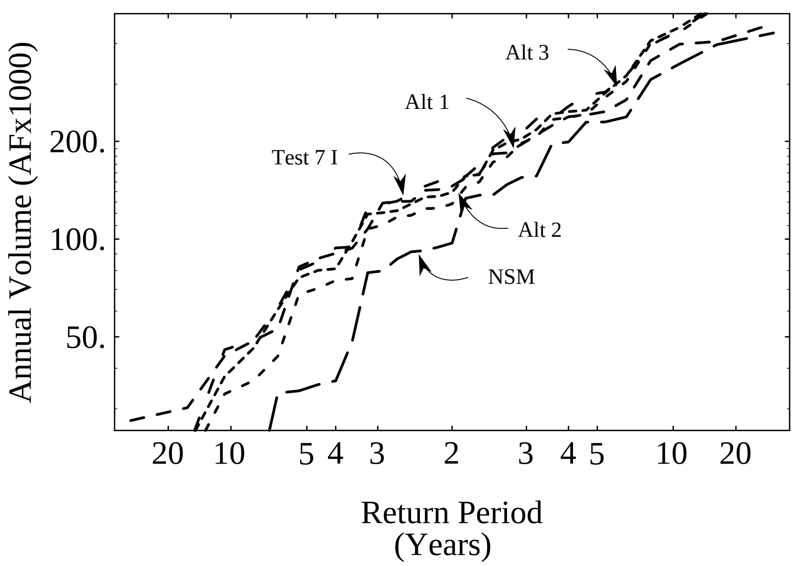


Figure 81: Frequency of annual freshwater inflows into Florida Bay.

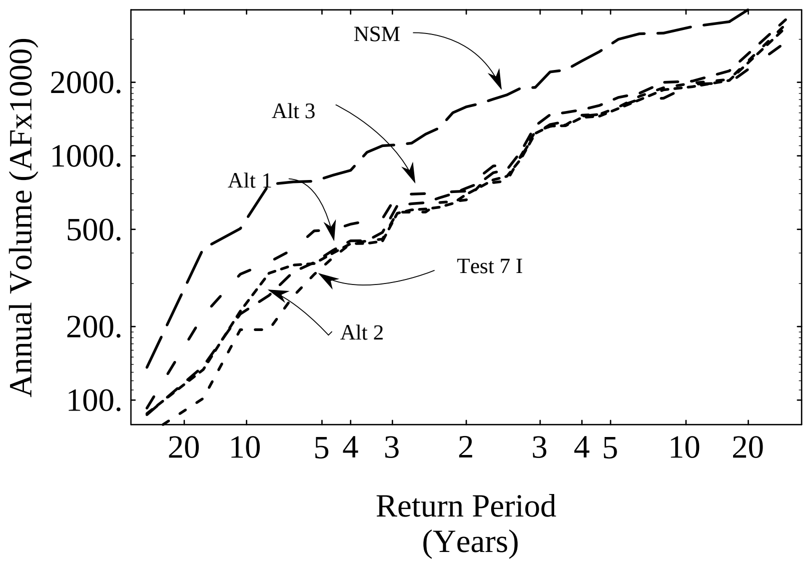


Figure 82: Frequency of annual freshwater inflows into the Shark Slough estuaries.

to examine simulated annual flow volumes. The frequency of annual flow volumes towards Florida Bay for the alternatives being considered is shown in Figure 81 . The desired condition is to provide flows that are similar to those predicted by the Natural Systems Model. According to these simulations freshwater inflows towards Florida Bay are similar for each of the three alternatives. There is also little difference between the three alternatives and Test 7 Phase I. The three alternatives and the Experimental Water Deliveries Program both produce flows that are somewhat higher than those expected under Test 7 Phase I conditions and NSM. According to these simulations all three of the alternatives might be expected to produce more suitable crocodile and manatee habitat than under NSM. As discussed above, these results appear inconsistent with the predicted salinity categories used to determine crocodile habitat suitability.

Figure 82 shows the frequency of input of annual flow volumes towards Shark Slough estuaries for the alternatives being considered. The freshwater inflows under Alternatives 1 and 2 are similar to Test 7, and significantly lower than NSM. Although lower than NSM the flow volumes under Alternative 3 are slightly higher than flows predicted for the other alternatives and the Experimental Water Deliveries Program. Therefore alternative 3 is moving in the direction of restoration. Alternative 3 might be expected to produce slightly more suitable crocodile habitat than alternatives 1 and 2, and the Experimental Water Deliveries Program.

Figure 58 (page 71) shows the Crocodile Habitat Suitability graph for the North River Mouth. As with the basins of northeastern Florida Bay, the desired condition is to increase the percent of months in the low salinity category and reduce the percent of months in the high salinity category. According to these simulations alternatives 1 and 2 increase the percent of months in the high salinity category and reduce the percent of months in the lower salinity category compared to the 1983 Base Condition. According to these simulations alternatives 1 and 2 produce less suitable crocodile and manatee habitat than under the 1983 Base Condition. Alternative 3 produces a percentage of months in each salinity category similar to the 83 Base Condition which is an improvement over both Alternatives 1 and 2, and Test 7 Phases I and II. According to these simulations Alternative 3 might be expected to produce slightly somewhat more suitable crocodile and manatee habitat in the western Everglades estuaries than under the two other alternatives or the Experimental Water Deliveries Program.

Figure 83 shows the distribution of mean monthly flow volumes towards Shark Slough for the alternatives being considered. As with northeastern Florida Bay, the desired condition is to match the pattern of monthly flow distribution as predicted by NSM. According to these simulations alternative 3 produces a distribution pattern that is somewhat similar to NSM. However, the monthly flow volumes under alternative 3 are still significantly less than NSM. Alternative 3 produces flows that are slightly less than or equal to Test 7 Phase I and II during the early wet season. However, during the critical crocodile hatchling survival months of October - December and during the early dry season, alternative 3 provides monthly flow volumes slightly greater than or equal to the Experimental Water Deliveries Program. Little or no change in favorable salinity ranges for crocodile hatchlings can be expected. During the dry season, alternative 3 shows some evidence of the lag flows characteristic of the natural system, unlike the EWD. The slight increase in flows and slight improvement in pattern of flows during the fall and early winter months, suggest that Alternative 3 might produce slightly more suitable crocodile habitat than the Experimental Water Deliveries.

3.2.4 Snail Kite

To assess the possible effects of proposed Alternatives to the Experimental Water Deliveries Program on snail kites the same methods previously described were applied. According to this evaluation method Tables 18–25, beginning on page 111, suggest that under Alternative 1 the conditions for snail kites remain favorable, similar to those predicted for the existing conditions (as represented be Test 7 Phase I), in Basin 14, Southern 3A, and Western 3B.

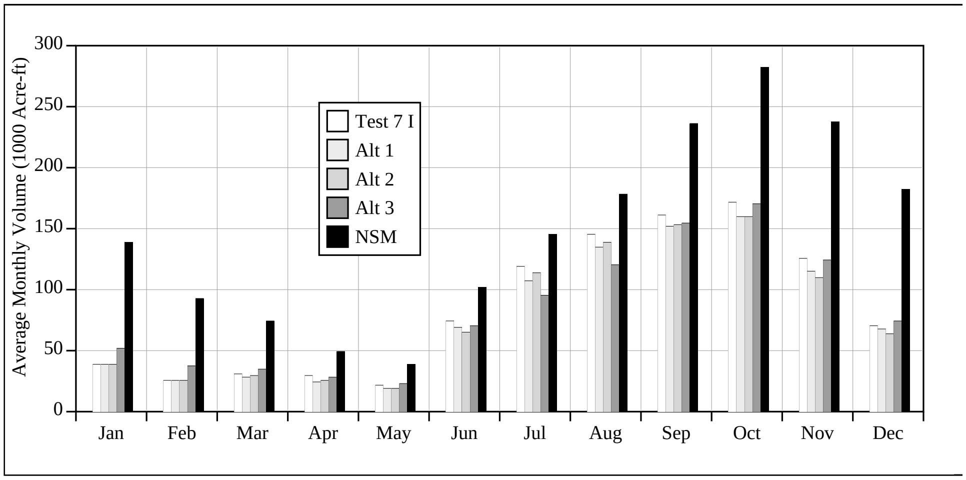


Figure 83: Average monthly inflows towards Shark Slough for the alternatives investigated.

Western WCA-3A would be slighly les favorable for kites in Alternative 1. It appears there would be little or no change, between Test 7 and Alternative 1, in the areas currently used by nesting kites. Elsewhere under Alternative 1 conditions remain generally unfavorable, again similar to those predicted for Test 7. Under Alternative 3, compared to Test 7, conditions appear to generally worsen in the areas currently used by nesting kites. However, conditions become slightly more favorable in Shark Slough. Conditions in Eastern 3B remain the same as those predicted for Test 7, unfavorable.

Looking only at the frequency of drying events, Table 26 suggests that under Alternative 1 only Indicator Region 14 (Southern WCA-3A), Southern 3A Snail Kite Habitat and Western 3B are predicted to provide suitable or marginal conditions for snail kites. These conditions are similar to or slightly worse than those predicted for Test 7. Elsewhere under Alternative 1 conditions remain generally unfavorable, similar to those predicted for Test 7. Under Alternative 3, compared to Test 7, conditions appear to generally worsen in the areas currently used by nesting kites. It appears that drying events occur too frequently in these areas. However, conditions become slightly more favorable in Shark Slough, with the occurrence of drying events decreasing somewhat so that marginal conditions for snail kites are predicted. Under Alternative 3 the frequency of drying events increases in Eastern 3B resulting in snail kite conditions remaining unsuitable, the same as those predicted for Test 7. Overall, considering the two evaluation methods, it appears that in general Alternative 1 either does not significantly change hydrological conditions in habitats used by nesting kites or makes conditions slightly worse. Overall, it appears that in general Alternative 3 makes hydrological conditions worse in habitats currently used by nesting kites (WCA-3A), and provides for only a slight improvement in potential kite habitat elsewhere (Shark Slough).

Tables 18–26 are summary tables of hydrologic conditions in WCA-3A, 3B, and Everglades National Park, with respect to snail kite habitat, generated from Figures 165–203. These figures are included in Appendix A.2 for completeness. Figures 174– 179 are a measure of the stage at which ponded levels are below for 30 consecutive days. Figures 180– 187 are a measure of the frequency of the 1 day minimum ponded levels. Figures 188– 194 are a measure of the frequency of the 1 day maximum ponded levels. Figures 196– 202 are a measure of the frequency of the annual 30-day average maximum ponded levels. Figures 204– 210 are a measure of the frequency for the maximum number of days of continuous dryout between January 1 and April 30.

3.3 Conclusions on Effects of Alternatives on Endangered Species

With respect to the Cape Sable seaside sparrow, we have the following conclusions:

- The SFWMD's proposal in the Lower East Coast Water Supply Plan, (Alternative 5 Phase I) is an example of a delivery scheme which provides uniformly better conditions for subpopulation A while not creating adverse conditions downstream.
- Plans which make relatively small structural modifications but leave the Rainfall Plan and the Water Conservation Area 3A regulatory schedule largely intact seem to mixed benefits for the western subpopulations.
- Alternatives which bring L-31N stages to the 1983 Base Conditions improve conditions for subpopulations E and F.
- Alternatives which route most flows into Taylor Slough at S-332D rather than into lower C-111 improve conditions in subpopulation D.
- Information about the effects of S-332D (Test 7 Phase II) operations is inconclusive.

With respect to the wood stork, we have the following conclusions:

- For Shark Slough, Alternative 3 provides about a 8% improvement in habitat conditions over the Experimental Water Deliveries Program, approaching that predicted

Western WCA-3A Snail Kite Habitat						
Indicator	NSM	1983 Base	Test 7 Phase I	Alternative 1	Alternative 2	Alternative 3
Median Hydroperiod (days/year)	**358**	365	360	**359**	365	**317**
Fraction of years hydroperiod less than 310 days	**0.39**	**0.35**	**0.35**	**0.36**	0.35	**0.42**
Fraction of years there is a drying event	**0.63**	0.55	**0.61**	**0.68**	0.51	**0.77**
Fraction of years there is a drying event lasting 30 days or longer	0.42	**0.45**	0.42	**0.48**	0.42	**0.58**
Fraction of years there is a drying event before May	0.55	0.54	**0.55**	**0.59**	0.48	**0.64**

Table 18: Summary of selected measures related to the snail kite for the Western 3A Snail Kite Habitat. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Southern WCA-3A Snail Kite Habitat						
Indicator	NSM	1983 Base	Test 7 Phase I	Alternative 1	Alternative 2	Alternative 3
Median Hydroperiod (days/year)	365	365	365	365	365	362
Fraction of years hydroperiod less than 310 days	0.28	**0.07**	0.10	0.11	0.08	0.29
Fraction of years there is a drying event	0.53	0.34	0.33	0.34	0.32	0.58
Fraction of years there is a drying event lasting 30 days or longer	0.35	0.19	0.19	0.19	**0.10**	0.42
Fraction of years there is a drying event before May	0.49	0.18	0.18	0.18	**0.10**	0.45

Table 19: Summary of selected measures related to the snail kite for southern Snail Kite habitat. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 14: Southern WCA-3A						
Indicator	NSM	1983 Base	Test 7 Phase I	Alternative 1	Alternative 2	Alternative 3
Median Hydroperiod (days/year)	365	365	365	365	365	365
Fraction of years hydroperiod less than 310 days	0.32	**0.07**	0.07	**0.07**	0.09	0.25
Fraction of years there is a drying event	0.51	0.26	**0.23**	0.28	**0.17**	0.40
Fraction of years there is a drying event lasting 30 days or longer	0.39	**0.10**	**0.10**	0.13	**0.06**	0.29
Fraction of years there is a drying event before May	0.48	**0.09**	**0.11**	0.11	**0.07**	0.31

Table 20: Summary of selected measures related to the snail kite for Indicator Region 14: Southern WCA-3A. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 15: Western WCA-3B						
Indicator	NSM	1983 Base	Test 7 Phase I	Alternative 1	Alternative 2	Alternative 3
Median Hydroperiod (days/year)	**359**	365	365	365	365	365
Fraction of years hydroperiod less than 310 days	0.30	0.33	0.23	0.31	0.22	0.32
Fraction of years there is a drying event	0.58	0.44	0.40	0.42	0.41	0.55
Fraction of years there is a drying event lasting 30 days or longer	0.39	0.35	0.35	0.35	0.35	**0.45**
Fraction of years there is a drying event before May	0.52	0.35	0.30	0.32	0.27	0.44

Table 21: Summary of selected measures related to the snail kite for Indicator Region 15- West WCA-3B. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 16: Eastern WCA-3B						
Indicator	NSM	1983 Base	Test 7 Phase I	Alternative 1	Alternative 2	Alternative 3
Median Hydroperiod (days/year)	365	**272**	**300**	**294**	**295**	**289**
Fraction of years hydroperiod less than 310 days	0.19	**0.71**	**0.59**	**0.61**	**0.60**	**0.62**
Fraction of years there is a drying event	0.50	**0.92**	**0.80**	**0.77**	**0.75**	**0.83**
Fraction of years there is a drying event lasting 30 days or longer	0.32	**0.81**	**0.65**	**0.68**	**0.65**	**0.71**
Fraction of years there is a drying event before May	0.40	**0.79**	**0.65**	**0.64**	**0.64**	**0.71**

Table 22: Summary of selected measures related to the snail kite for Indicator Region 16- East WCA-3B. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 11: Northeast Shark Slough						
Indicator	NSM	1983 Base	Test 7 Phase I	Alternative 1	Alternative 2	Alternative 3
Median Hydroperiod (days/year)	365	**277**	**352**	**348**	**311**	365
Fraction of years hydroperiod less than 310 days	**0.06**	**0.74**	**0.39**	**0.42**	**0.55**	0.31
Fraction of years there is a drying event	**0.14**	**0.95**	0.58	0.58	**0.70**	0.45
Fraction of years there is a drying event lasting 30 days or longer	**0.10**	**0.81**	**0.48**	**0.52**	**0.58**	0.35
Fraction of years there is a drying event before May	**0.03**	**0.88**	**0.56**	**0.56**	**0.64**	0.35

Table 23: Summary of selected measures related to the snail kite for Indicator Region 11- Northeast Shark Slough. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 10: Mid Shark Slough						
Indicator	NSM	1983 Base	Test 7 Phase I	Alternative 1	Alternative 2	Alternative 3
Median Hydroperiod (days/year)	365	365	363	**352**	**350**	365
Fraction of years hydroperiod less than 310 days	**0.06**	0.14	0.32	**0.36**	**0.41**	0.24
Fraction of years there is a drying event	**0.19**	0.45	0.55	0.58	**0.61**	0.40
Fraction of years there is a drying event lasting 30 days or longer	**0.10**	0.32	0.42	**0.45**	**0.52**	0.32
Fraction of years there is a drying event before May	**0.03**	0.29	0.45	0.51	**0.58**	0.31

Table 24: Summary of selected measures related to the snail kite for Indicator Region 10- Mid- Shark Slough. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 9: SW Shark Slough						
Indicator	NSM	1983 Base	Test 7 Phase I	Alternative 1	Alternative 2	Alternative 3
Median Hydroperiod (days/year)	365	365	**357**	**350**	**343**	365
Fraction of years hydroperiod less than 310 days	0.09	0.25	**0.37**	**0.37**	**0.41**	0.28
Fraction of years there is a drying event	0.25	0.47	0.60	0.61	**0.73**	0.40
Fraction of years there is a drying event lasting 30 days or longer	0.13	0.39	**0.48**	**0.45**	**0.48**	0.32
Fraction of years there is a drying event before May	0.14	0.40	**0.56**	**0.57**	**0.64**	0.30

Table 25: Summary of selected measures related to the snail kite for Indicator Region 9- SW Shark Slough. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Basin	NSM	83 Base	Test 7 Phase I	Alternative 1	Alternative 2	Alternative 3
Western 3A Snail Kite Habitat	0.63	0.55	0.61	0.68	0.51	*0.77*
IR 14- Southern WCA-3A	0.51	**0.26**	**0.23**	**0.28**	*0.17*	*0.40*
Southern 3A Snail Kite Habitat	0.53	*0.34*	**0.33**	*0.34*	**0.32**	0.58
IR 15-West WCA-3B	0.58	*0.44*	*0.40*	*0.42*	*0.41*	0.55
IR 16-East WCA-3B	0.50	0.92	0.80	0.77	0.75	0.83
IR 11-Northeast Shark Slough	0.14	0.95	0.58	0.58	0.70	*0.45*
IR 10-Mid-Shark Slough	*0.19*	*0.45*	0.55	0.58	0.61	*0.40*
IR 9- SW Shark Slough	0.25	*0.47*	0.60	0.61	0.73	*0.40*

Suitability Legend

Condition	Range[a]	Type font
Unsuitable	$f <= 0.16$	Roman
Marginal	$0.16 < f <= 0.19$	*Italic*
Suitable	$0.20 < f <= 0.33$	**Bold**
Marginal	$0.33 < f <= 0.49$	*Italic*
Unsuitable	$f > 0.49$	Roman

[a] Where f is the exceedence frequency of a dryout.

Table 26: Summary by basin of the fraction of years there is a drying event at or below ground surface, classified as suitable, marginal, or unsuitable.

for the 83 Base. This measure of improvement assumes a linear relationship between hydropattern improvement and habitat improvement.

- For Shark Slough, Alternatives 1 and 2 are very similar to Test 7 Phases I and II and predicted to have no effect little or no effect on wood stork foraging habitat conditions in the region of the traditional Shark Slough estuarine stork nesting colonies, compared to the current conditions.

- When Shark Slough and Taylor Slough are considered together the combined scores suggest that overall Alternatives 1 and 2 are again very similar to Test 7 Phases I and II and predicted to have little or no effect on wood stork foraging habitat, compared to current conditions.

- When Shark Slough and Taylor Slough are considered together, Alternative 3 provides the greatest improvement (19%) in habitat conditions over the 83 Base, and an 11 - 14% improvement over the Experimental Water Deliveries Program.

- Again, it should be noted that the combined total scores are significantly affected by the large increases predicted for Taylor Slough flows (117 - 140%) under Experimental Water Deliveries and the Alternatives. It should not be assumed that a flow for Taylor Slough that averages well above NSM is benefiical for storks. It may be just as detrimental ecologically as below average flow in Shark Slough (Ogden, pers. comm.)

With respect to the crocodile, we have the following conclusions:

Summary

- The suspect crocodile habitat suitability measures for northeastern Florida Bay suggest that alternatives 1 and 2 either do not significantly change existing conditions or they make conditions less favorable for crocodiles and manatees.

- Based on the suspect crocodile habitat suitability measure, alternative 3 is expected to slightly improve conditions, moving habitat suitability closer to that predicted for 83 Base.

- However, total flow volumes into Florida Bay suggest that none of the alternatives, including alternative 3, are expected to significantly change the suitability of crocodile and manatee habitat from existing conditions.

- In the Shark Slough estuaries, the crocodile habitat suitability measure for North River Mouth suggests that alternative 1 and 2 either do not significantly change existing conditions or they make conditions less favorable for crocodiles and manatees.

- However, alternative 3 is expected to improve conditions, moving habitat suitability closer to that predicted for 83 Base.

- Total annual flow volumes for alternatives 1 and 2 do not suggest any improvement over existing habitat conditions for crocodile and manatee in the Shark Slough estuaries.

- Based on flow volumes into Shark Slough estuaries, simulations suggest that alternative 3 might be expected to improve habitat conditions, equaling, and in some cases exceeding the 83 Base.

- Simulations of the monthly distribution of flows into Shark Slough estuaries for alternative 3 suggest a distribution pattern somewhat similar to the natural system than the 83 Base. During the critical crocodile hatchling survival months of October - December and during the early dry season, alternative 3 provides monthly flow volumes slightly greater than the Experimental Water Deliveries Program. Little or no change in favorable salinity ranges for crocodiles and manatees can be expected.

- Given that under current conditions the overall number of crocodile nests in Everglades National Park appears to be stable or slightly increasing, that hatchling crocodiles are surviving from existing successful nests (Mazzotti, pers. com. 1998), and that alternative 3 is expected to have slightly beneficial or no effect on favorable crocodile habitat in northeastern Florida Bay and beneficial effects on crocodile habitat in Shark Slough estuaries, then alternative 3 is not likely to adversely affect the American crocodile in Everglades National Park.

- However, while information about the growth and survival of hatchling crocodiles is increasing, the data are still scant. In addition to monitoring nesting effort, distribution, and success, the monitoring of growth and survival of hatchling crocodiles, and the distribution of all size classes of crocodiles is considered a sensitive measure of population response to water deliveries alternatives. Growth and survival monitoring should be included as an appropriate action in any water management alternative considered.

With respect to the manatee, we have the following conclusions:

- Considering the relatively small proportion of the U.S. population of the Florida manatee that occur in northeastern Florida Bay (Snow 1991, 1992, 1993), and given that alternative 3 is expected to have slightly beneficial or no effect on favorable manatee habitat in northeastern Florida Bay and slightly beneficial or no effects on manatee habitat in Shark Slough estuaries, then it appears that alternative 3 is not likely to adversely affect the Florida manatee in Everglades National Park.

- The following manatee research and monitoring needs should be included as appropriate actions in any water management alternative considered; (1) continued long-term surveys of relative distribution and abundance, (2) mapping the seasonal distributions and composition of submerged aquatic vegetation communities, (3) documenting daily activity patterns and seasonal movements, especially related to the question of freshwater dependency.

With respect to the snail kite, we have the following conclucions:

- Overall, considering the two evaluation methods, it appears that in general Alternative 1 either does not significantly change hydrological conditions in habitats used by nesting kites or makes conditions slightly worse.

- Overall, it appears that in general Alternative 3 makes hydrological conditions worse in habitats currently used by nesting kites (WCA-3A), and provides for only a slight improvement in potential kite habitat elsewhere (Shark Slough).

- Alternative 3 is likely to result in a behavioral response (e.g. shifts in nesting and foraging distribution) by snail kites, however, any numerical response (e.g. changes in population size) is undetermined.

Chapter 4

Modified Water Deliveries and C-111 Projects

The Modified Water Deliveries Project was originally conceived primarily to improve conditions in Everglades National Park and the southern Everglades. Congress gave specific directions for the Modified Water Deliveries Project most recently through the Everglades National Park Protection and Expansion Act of 1989 (PL 101-229). The Act has as its stated purpose (Section 101(b))

> The purposes of this Act are to
>
> 1. increase the level of protection of the outstanding natural values of Everglades National Park and to enhance and restore the ecological values, natural hydrologic conditions and public enjoyment of such area by adding the area commonly known as the Northeast Shark River Slough and the East Everglades to Everglades National Park;
> 2. assure that the park is managed in order to maintain the natural abundance, diversity, and ecological integrity of native plants and animals, as well as the behavior of native animals, as part of their ecosystem.

Within the Everglades National Park Protection and Expansion Act of 1989, Congress authorized "modifications to the Central and Southern Florida Project to improve water deliveries to Everglades National Park, and to the extent practicable, take steps to restore the natural hydrologic conditions within the Park." (Section 104(a)). The Act authorizes the General Design Memorandum for Modified Water Deliveries to Everglades National Park [U.S. Army Corps of Engineers, 1992] to address these hydrologic modifications.

The Modified Water Deliveries General Design Memorandum (GDM) describes a plan to modify the surface water inflow patterns in an attempt to restore the Shark Slough hydrologic regime [U.S. Army Corps of Engineers, 1992]. The preferred plan developed by the Corps of Engineers and put forward in the GDM is shown in Figure 84. The plan calls for water controls structures of limited capacity between Water Conservation Areas 3A and 3B, as well as limited flow capacity between Water Conservation Area 3B and Everglades National Park. The plan also proposes a flood protection system for the developed area of west of L-31N, a tract known as the 8.5 square mile area. In addition to the structural components depicted in Figure 84, the GDM also contains an operational plan for each of the structures. The combination of the structural components and operational plans are what constitute the Modified Water Deliveries Project.

The interagency Southern Everglades Restoration Alliance (SERA) is the most recent development in Modified Water Deliveries Project. This organization is charged with coordinating the implementation of the Modified Water Deliveries Project while assuring it remains consistent with C-111 Project and EWD Program objectives. Figure 85 is a time line of some significant events in the process Modified Water Deliveries, as well some of the important historical milestones. Although SERA is responsible for the interagency project coordination, agencies retain traditional roles. In Modified Water Deliveries Project, the National Park Service funds the project, while the Corps is responsible for design and construction and the SFWMD is the local sponsor.

The C-111 Project is described in the C-111 General Reconnaisance Report (GRR) [U.S. Army Corps of Engineers, 1994]. This project consists primarily of a set of pumps long L-31N, a buffer between L-31N and Everglades National Park, and infrastructure to restore wetlands in lower C-111 (see Figure 84).

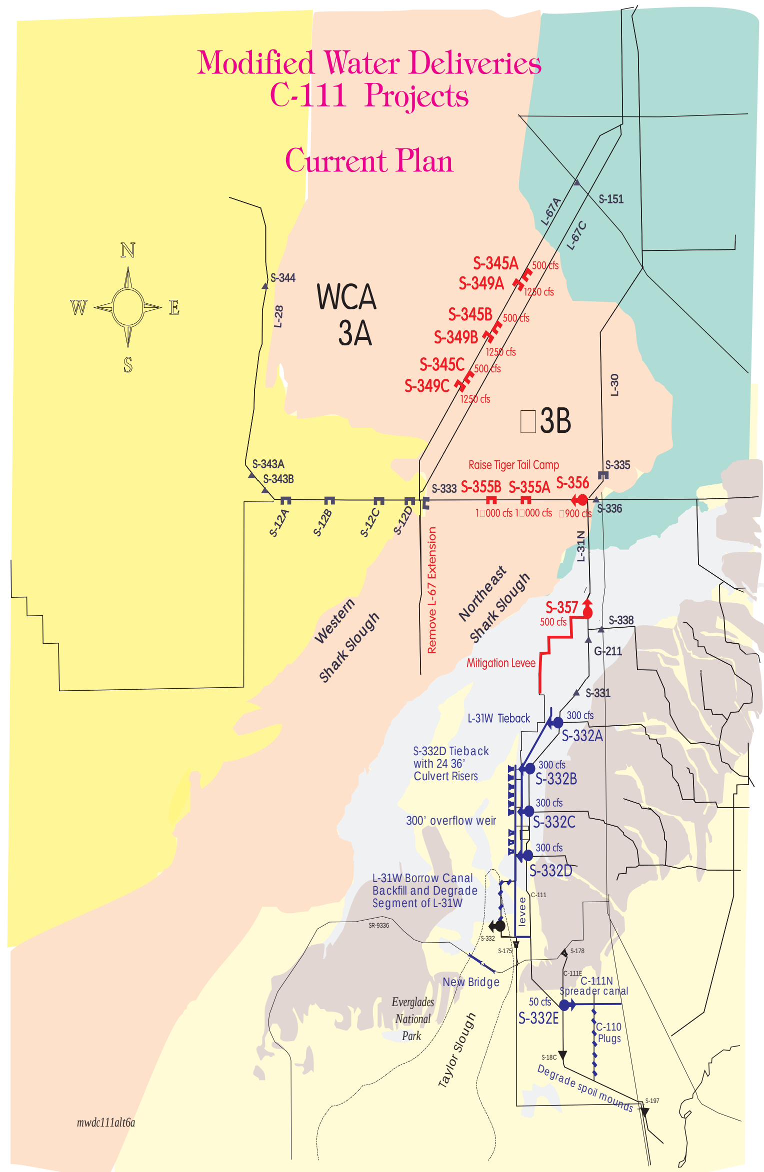


Figure 84: The preferred plan as recommended by the Modified Water Water Deliveries to Everglades National Park GDM.

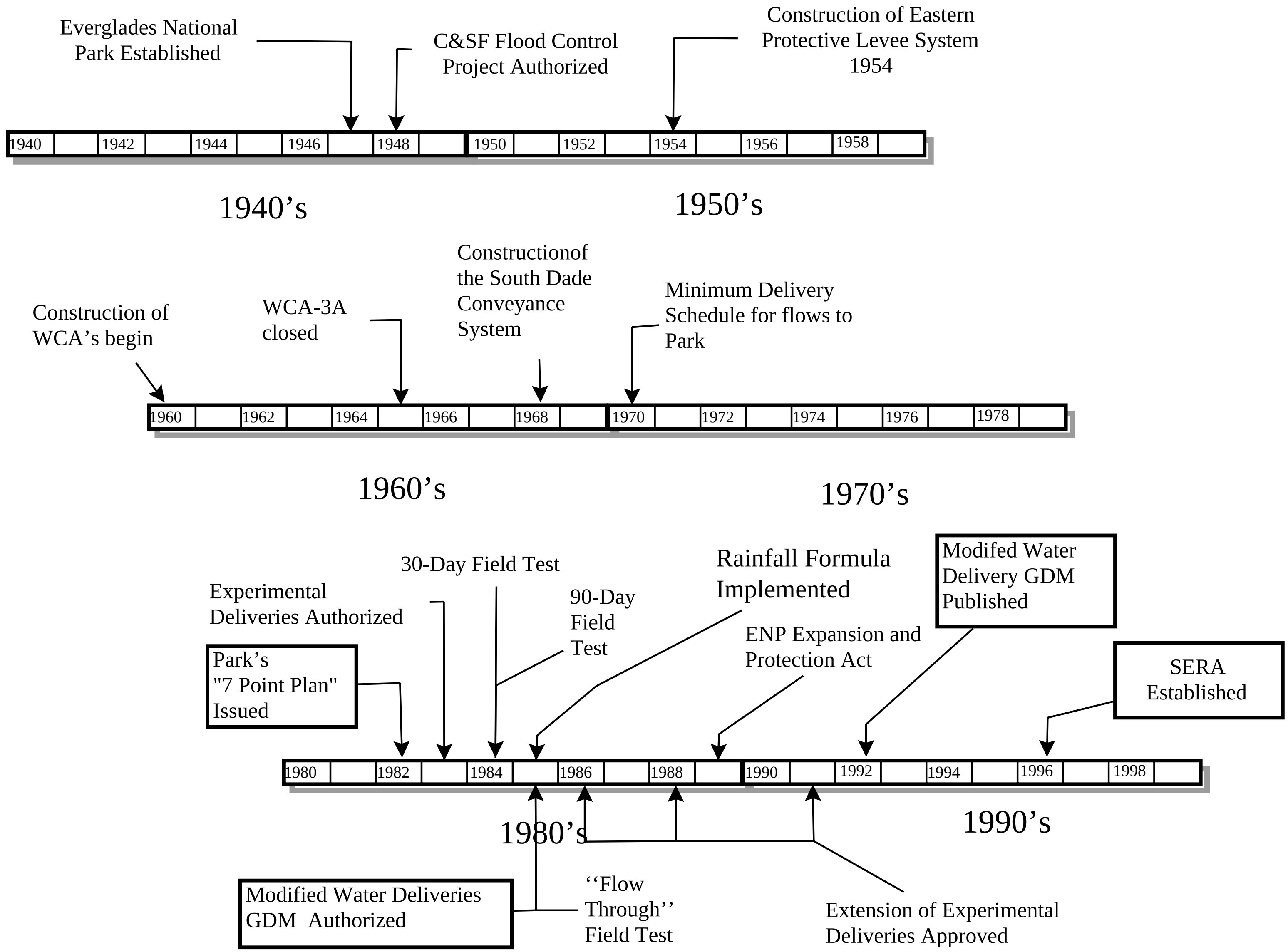


Figure 85: Timeline of significant events in the Modified Water Deliveries process.

Component	Current Analyses	1992 GDM
S-333	Close when TW > 7.5 ft	no TW restriction
S-355	Close when TW > 7.5 ft	no TW restriction
S-356	Close when TW > 7.5 ft	no TW restriction
S-331	Water Supply Only	Water Supply and Flood Control
S-12	Pass 100% of Zone B,C, D flows if S-333 closed	Pass 100% of Zone B releases if S-333 closed. Pass 45% of Zone C,D

Table 27: Summary of differences between 1992 GDM and simulations performed in this analysis.

4.1 Description of the Projects

The complete description of the Modified Water Deliveries Project is the the Corps' GDM [U.S. Army Corps of Engineers, 1992], and the C-111 Project is described in the C-111 GRR [U.S. Army Corps of Engineers, 1994]. Based upon descriptions in the GDM, there are a few important differences between the Corps' modeling assumptions and those used for this analysis. Table 27 is a summary of the operational and structural differences.

The most important difference between the GDM analysis and this analysis is the constraint on the L-29 borrow canal stage (see Figure 1 for location). The Corps assumed that the water level in this canal would not constrain operations in any way. Figure E-78 of the GDM [U.S. Army Corps of Engineers, 1992] shows that L-29 stages are not constrained; the period of simulation maximum is 9.80 ft msl and 35% of the time the canal stage is above 7.5 ft msl. From the earliest implementation of the Experimental Water Deliveries, stages exceeding 7.5 ft msl resulting in cutailment of S-333 inflows, primarily because of potential damage to Miccosukee camps and to Tamiami Trail. It is indeed possible that stages near 8.5 ft msl have the potential to damage Tamiami Trail. As water levels rise, capillary action pulls water into the road subbase, substantially decreasing the load-bearing capacity of the road, and potentially leading to failure. This analysis uses a constraint of 7.5 ft msl primarily because that is the maximum level currently allowed and a thorough analysis to determine the effects of stages above 7.5 ft msl has not, to our knowledge, been performed. Therefore, it is a very conservative assumption which minimizes the effects of high L-29 water levels. This constraint on L-29 affects two structures: S-355 (S-355 A&B are not modeled separately) and S-356. Both of these structures are assumed closed when L-29 stages exceed 7.5 ft msl.

The second important difference concerns S-331. As in the C-111 GRR [U.S. Army Corps of Engineers, 1994], we have assumed that S-331 is operated only in water supply mode, as designed. The rationale is that the flood operation mode operations are under the authority of the Experimental Water Deliveries Program. This authority should lapse when the Modified Water Deliveries Project is complete. The Corps' GDM [U.S. Army Corps of Engineers, 1992, p.F-17] assumes S-331 is operated to control L-31N stages at 5.0 feet. The result is that S-331, during wet years, was expected to pass in excess of 400,000 acre-ft southward.

4.2 Analysis of Modified Water Deliveries

One place to begin analyzing the hydrologic impacts of the Modified Water Deliveries Project is with an examination of the average annual structure flows. Figure 86 is a graphical depictions of the average annual structure flows computed by the SFWMM for Modified Water Deliveries. (Compare to 1983 Base water budget, found in Figure 3 on page 18 and to the Test 7 water budgets, found on pages 29 and 30, respectively). A comparision of the water budgets yields several noteworthy observations. First, the S-12 discharges are significantly decreased between Test 7 Phase I and Modified Water Deliveries. Second, in Modified Water Deliveries, the flow from Water Conservation Area 3A to 3B is large, averaging 125,000 acre-ft per year. Third, Modified Water Deliveries does not appear to substantially change the relative distribution between the S-12 structures and Northeast Shark Slough inflows, when compared to Test 7 Phase I.

We will organize the analysis of the hydrologic performance of Modified Water Deliveries and the C-111 Project by the following key components: Tamiami Trail stages and flows, WCA stages and flows, ENP stages and flows, and 8.5 Square Mile Area flood mitigation. We will take each in turn.

4.2.1 Tamiami Trail Stages and Flows

The starting point for examining stages and flows across Tamiami Trail is the L-29 Borrow Canal stage. Figure 87 compares the annual maximum stage frequencies for L-29. Modified Water Deliveries increases the L-29 borrow canal peak stages, with the 1-in-10-year stage increasing from 7.8 ft to 8.3 ft msl. Also, the median annual maximum stage is about 7.6

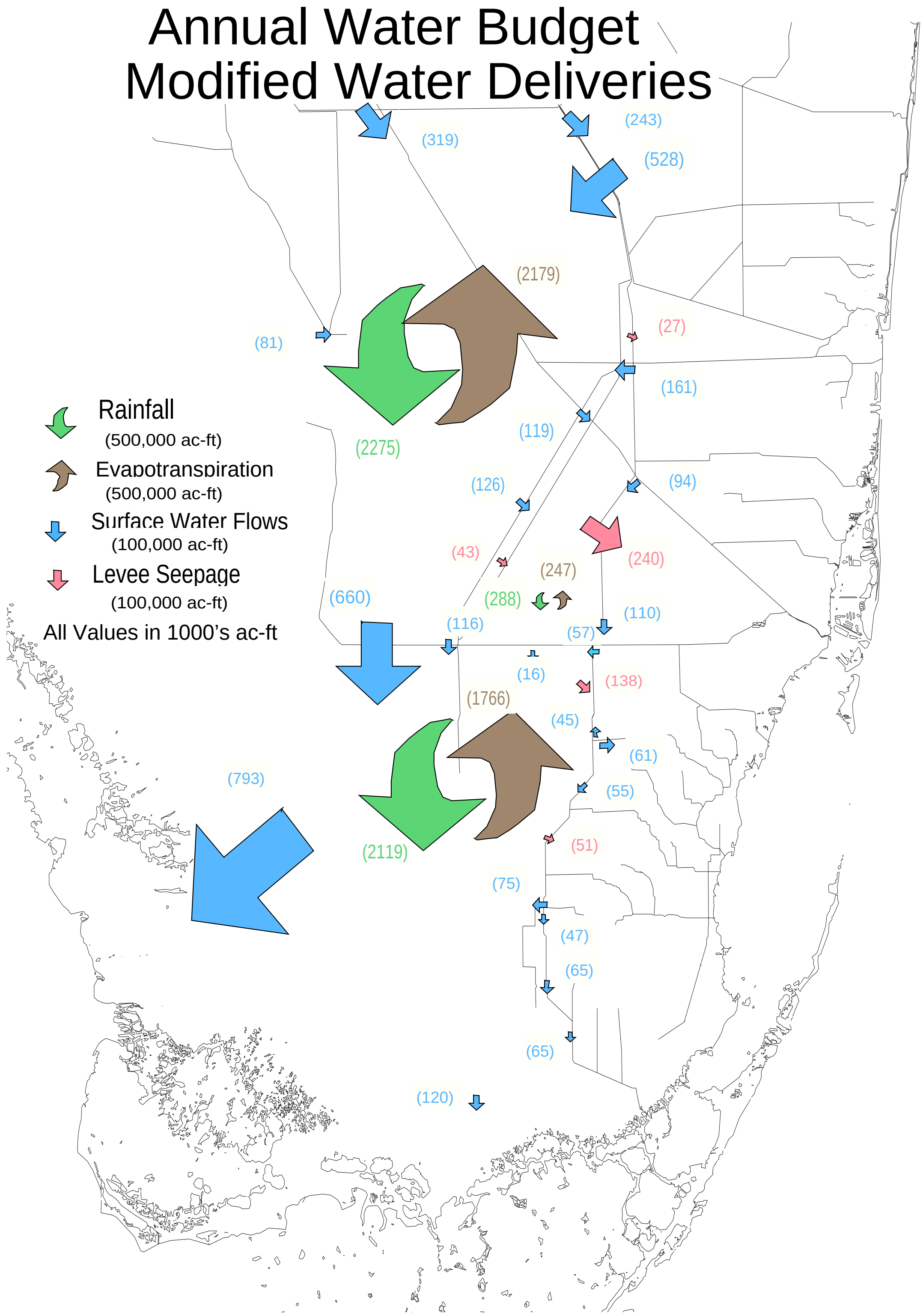


Figure 86: Average annual structure flows computed by the SFWMM for Modified Water Deliveries.

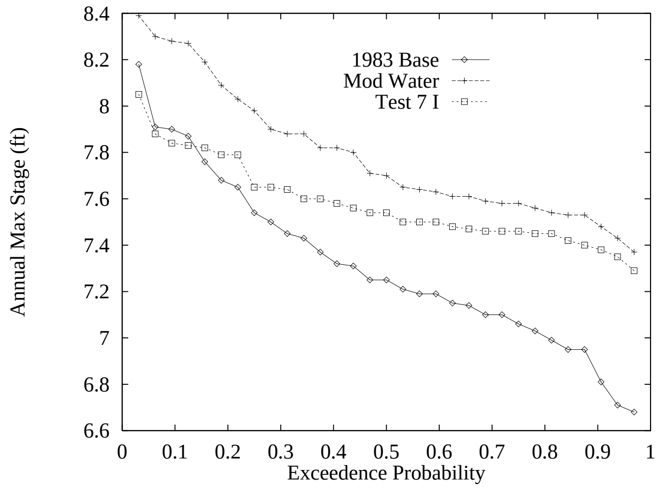
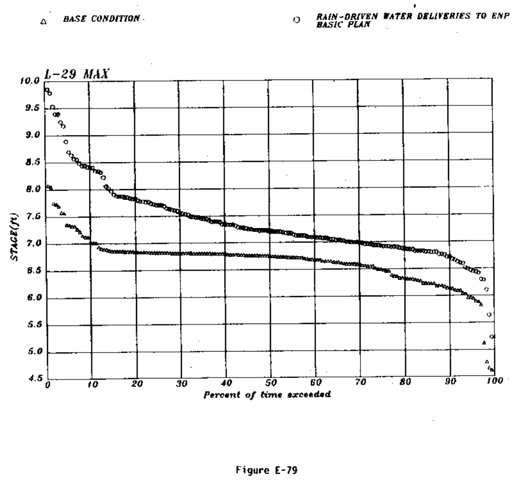


Figure 87: Annual maximum stages in L-29 Borrow Canal.

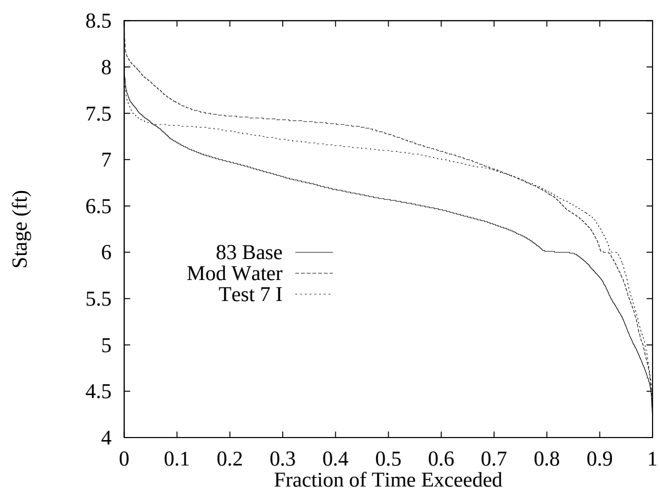
ft msl in Modified Water Deliveries. This implies that S-355 and S-356 will have tailwater restrictions preventing their use for some part of the year approximately one year out of every two. Although Test 7 and Modified Water Deliveries have the same constraint relative to L-29, Modified Water Deliveries has a slightly higher annual peak stage. This is due to higher WCA-3B stages, which increase the seepage into the canal.

The GDM [U.S. Army Corps of Engineers, 1992, p.E-79] plotted stage duration curves, rather than the frequency of annual maximum stages. Figure 88 compares the Corps' stage duration curve to that calculated in this analysis. The base cases are very similar (differences occur because of model version and simulation period), while the Modified Water Deliveries differences reflect the differing assumptions about an L-29 constraint to S-355 and S-356. The Corps' simulation estimates that L-29 stages will be above 7.5ft msl about 35% of the time, and above 8.5 ft msl about 8% of the time. The current simulation estimates that stages higher than 7.5 ft are greater than the 1-in-10-year event; the peak stage over the entire simulation period is 8.1 ft.

The L-29 stage is important because it bears directly on the flow across Tamiami Trail. The first is simply the volume of flow, i.,e., how much water crosses the Trail. The next is the spatial distribution of flow, or where the flow crosses Trail. The third is the timing of flows, or the time of year that flows occur. Each is essential to a restored and functional hydrologic regime with in Everglades National Park, and we take each of these in turn.



(a) GDM Figure E-79 [U.S. Army Corps of Engineers, 1992]



(b) Current Analysis

Figure 88: Comparisons of L-29 stage duration curves between the GDM and the current analyses.

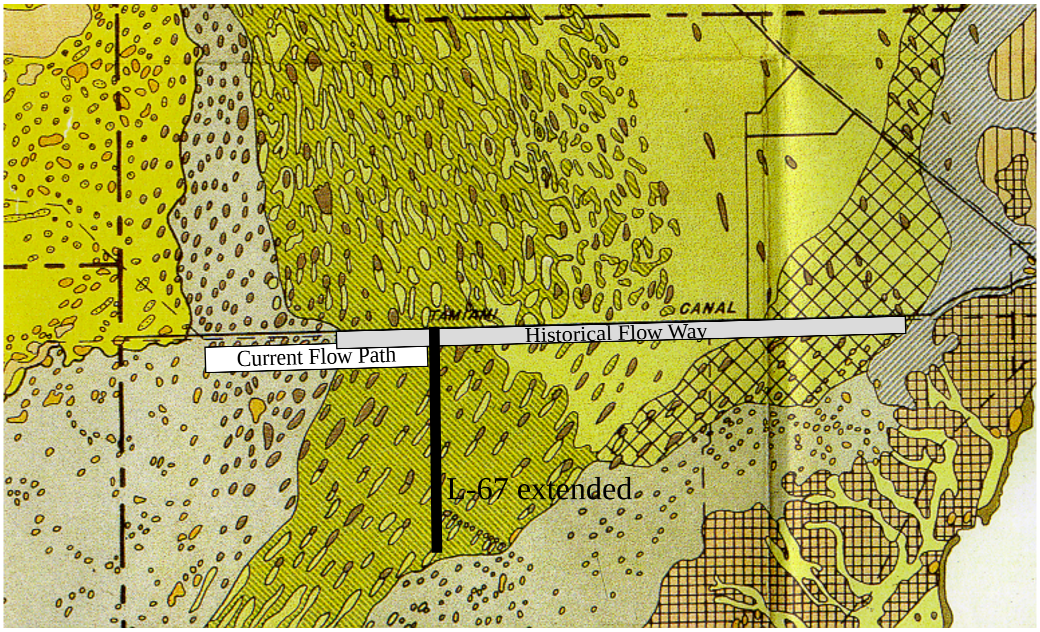
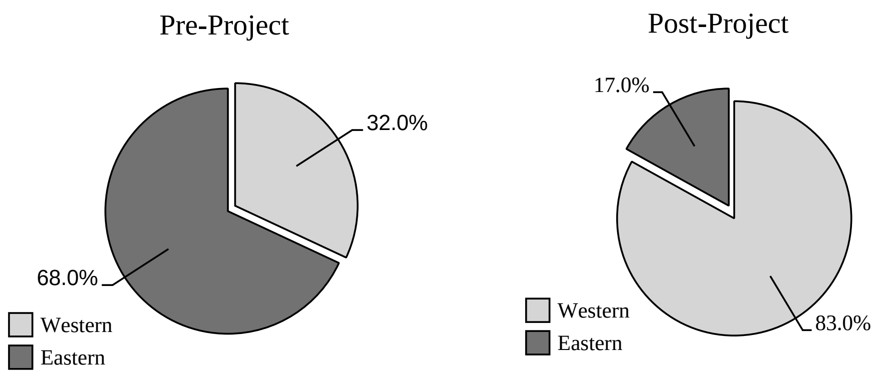


Figure 89: Reduction and shift of the historical Shark Slough flow way, after Davis [1943].

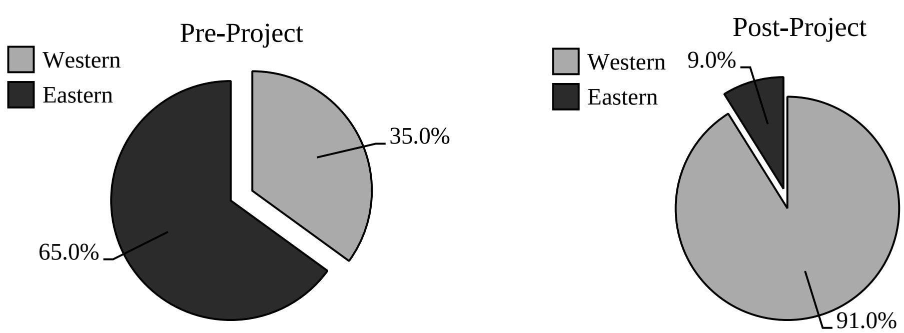
Spatial Distribution

The spatial distribution refers to where the water actually enters Shark Slough from Water Conservation Areas. Figure 89 shows how the historical Shark Slough flow path has been constricted and shifted to the west. Figure 90 shows the relative amounts of water entering eastern and western Shark Slough. (The dividing line is taken as the L-67 extended levee, as shown in Figure 89). Comparing pre-Project to post-Project, one can clearly see a shift. Prior to drainage, eastern Shark Slough carried the bulk of the water; with the construction of the C& SF Project, flows shifted to the west. Even with Experimental Water Deliveries Program, this fundamental problem remains uncorrected. During flood releases, flow into eastern Shark Slough is cut-off, and large volumes of water are dumped into western Shark Slough through the S-12 structures.

In Modified Water Deliveries, as in the Experimental Program, the objective is to split the deliveries 45% into western Shark Slough and 55% into eastern Shark Slough. These data are based on the historical observations, shown in Figure 91. However, as seen from the historical data, this conservatively estimates the split. During low flows, there is considerable scatter in the data. Most likely, the distribution was determined by the spatial and temporal characteristics of storms in the upstream watershed. However, during high discharge events,



(a) Average Flow Distribution: Eastern vs. Western Shark Slough



(b) Flow Distribution in Wet Years: Eastern vs. Western Shark Slough

Figure 90: Flow distribution in eastern and western Shark Slough pre- and post-C&SF Project based upon observed flows.

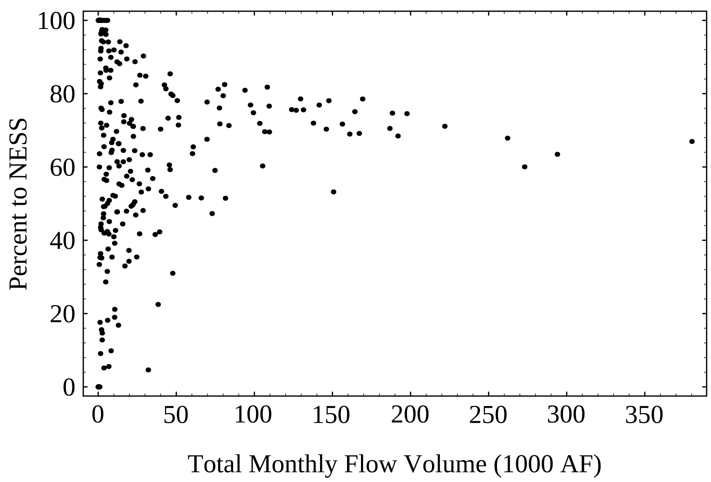
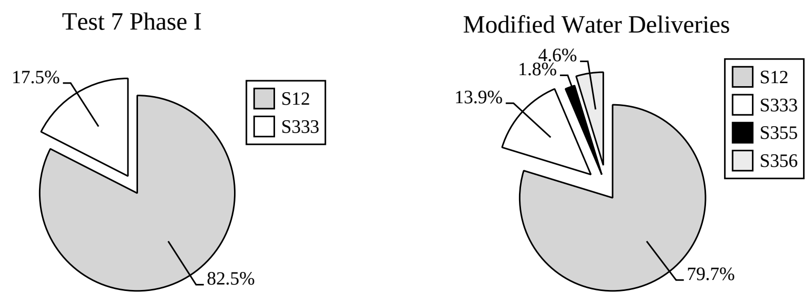


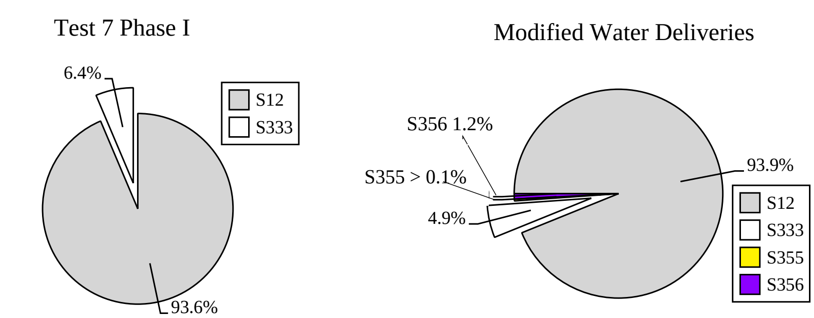
Figure 91: Fraction of monthly flow volume into eastern Shark Slough as a function of the total monthly flow volume.

the data scatter decreases and the observed split was more on the order of 30% west and 70% east. During these events, there was more or less uniform flow and the split represents the characteristics of Everglades conveyance.

To examine how well Modified Water Deliveries restores this historical spatial distribution, we can create a figure similar to Figure 90 for Test 7 Phase I and Modified Water Deliveries SFWMM simulations. Figure 92 summarizes the distribution of flows. The relative contribution of Northeast Shark Slough increases slightly on the average, but still remains fundamentally skewed from the historical distribution shown in Figure 90. The reason for the skew towards the east is explained in Figure 92(b). During wet periods, which account for the bulk of the flow volumes in the Everglades, almost the entire flow into Shark Slough enters through the S-12 structures, the same as the 1983 Base Condition and the situation today. So, rather than passing the desired 55 to 70% of the total discharge into Northeast Shark Slough during wet periods, Modified Water Deliveries passes almost 100% into western Shark Slough, which represents no improvement to either the 1983 Base condition or Test Iteration 7 of the Experimental Water Deliveries Program.



(a) Average Flow Distributions: 1965–1995



(b) Wet Year Flow Distributions: 1994–1995

Figure 92: Relative contributions of inflows into Everglades National Park for Test 7 Phase I and Modified Water Deliveries based upon the SFWMM.

Volumes

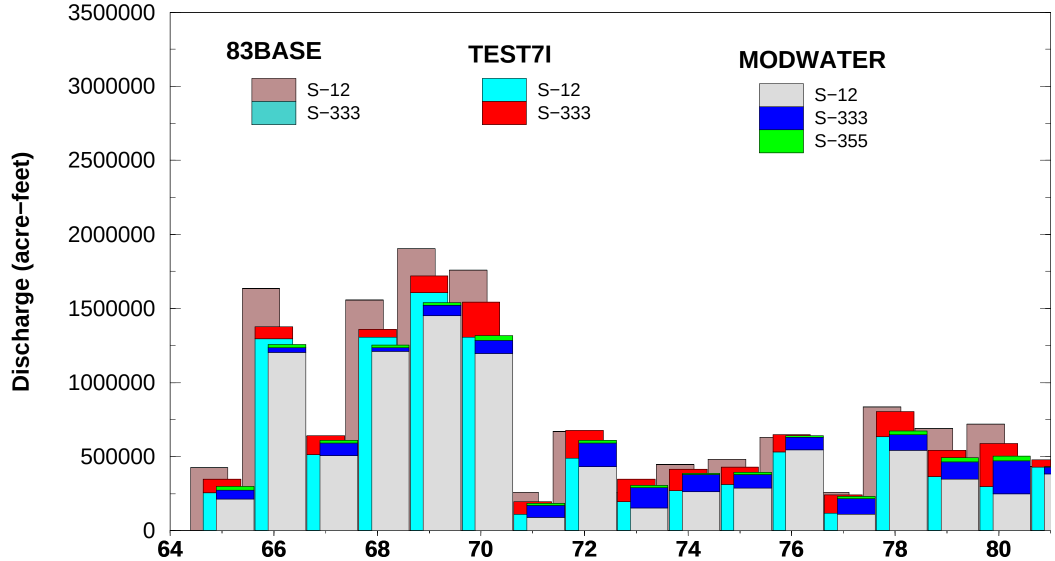
One can further examine the behavior of flow across Tamiami Trail by looking at the flow volumes at individual structures. Figure 93 compares the flows across Tamiami Trail (S-12, S-333, and S-355 structures) for the 1983 Base, Test 7 Phase I, and Modified Water Deliveries. Note that Modified Water Deliveries substantially decreases S-12 discharges relative to the 1983 base and Test 7 in all but the wettest years. However, the target 45-55% distribution appears to be achieved only during average or below average rainfall conditions. Note also that S-333 generally passes more flow that S-355.

In terms of flow frequency, Figure 94 compares annual flow volume across Tamiami Trail for the 1983 Base, Test 7 Phase I, and Modified Water Deliveries. Among the most important conclusions are that

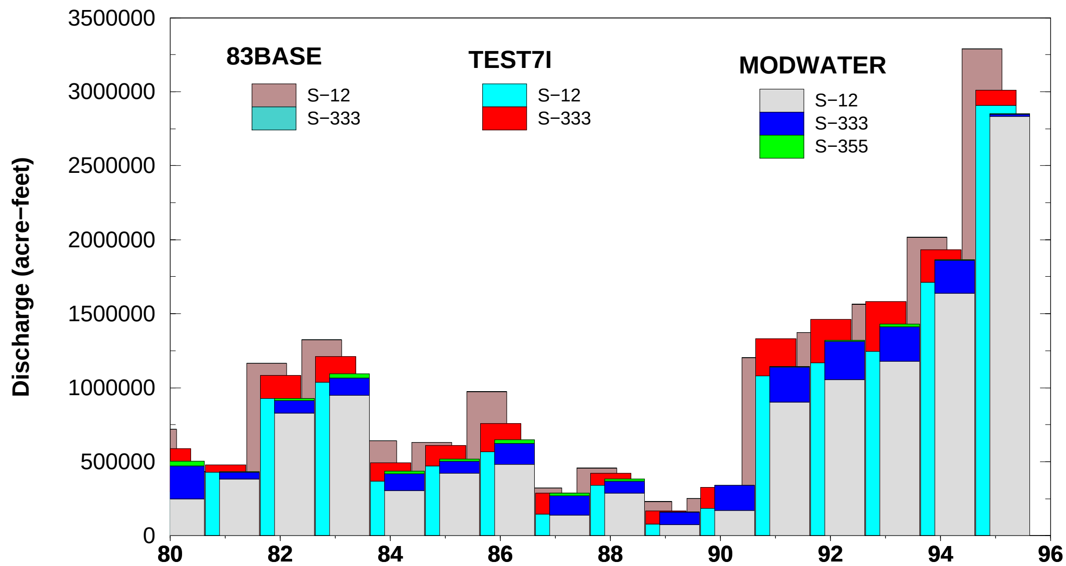
1. Modified Water Deliveries has lower total flows than the 1983 Base.
2. Modified Water Deliveries has very similar flows as Test 7 Phase I, but significantly lower during average and slightly wetter than average years. (Figure 94 has a logarithmic scale, which obscures the magnitude of difference.) This is understandable, as Modified Water Deliveries and Test 7 Phase I have very similar operational rules.
3. As conditions become very wet, all three plans are essentially the same.

Figures 95–Figures 96 are comparisons of S-12, S-333, and S-355 daily discharges relative to the Test Iteration 7 Phase I and Modified Water Deliveries. There are a number of features to note here. First, the "spikiness" of the S-12 releases was greatly reduced in both Modified Water Deliveries and Test 7 Phase I relative to the 1983 Base. This is certainly one of the most important accomplishments of the Experimental Water Deliveries, and Modified Water Deliveries maintains this significant environmental benefit. What's more, Modified Water Deliveries clearly reduces the number of brief regulatory discharge events. Again, this should be viewed as an important beneficial consequence of the Modified Water Deliveries Project.

Also, from these figures one can see the results in terms of structure flows of the operational strategy for the combination of S-333, S-355, and S-12. The S-355 structures are used to pass considerable flow during average conditions, but is insufficient to pass even average flows into Northeast Shark Slough. In "normal" years, such as 1972–1974, for example, S-333 passes much more than S-355 in order to meet eastern Shark Slough flow targets.



(a) 1965–1980



(b) 1981–1995

Figure 93: Comparison of Tamiami Trail annual flow volumes.

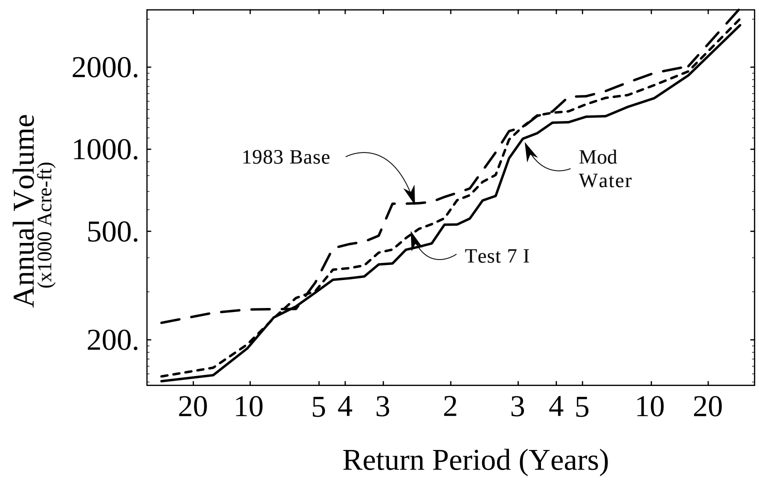
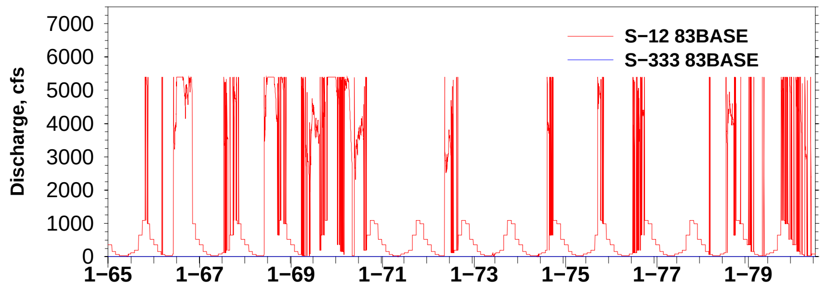


Figure 94: Return frequency for annual flow volumes across Tamiami Trail.

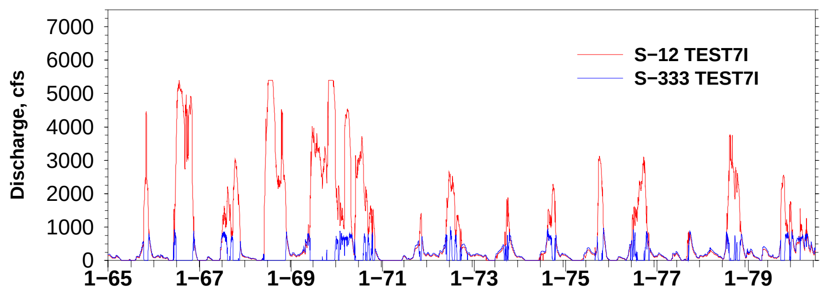
The decrease in flows during average and below average rainfall years is a consequence of operational policy, not structural limitations. That is, most likely this disbenefit can be corrected by some other set of operational rules. However, the response of the Project during wet years is determined primarily by structural capacity and infrastructure limitations. During floods (such as 1968, 1969, 1994, and 1995), S-333 and S-355 are largely non-operational. During flood conditions, the constraints imposed by limiting stages in L-29 severely curtails its use. However, even if the L-29 constraint to flow were removed, it is not likely that the S-355 structures would result in the desired 45-55% west-east distribution. To get a perspective on the capacity limitations, one can examine the historical data.

The Department of the Interior has a standard procedure for determining the magnitude of high flows.[U.S. Dept. of the Interior, 1982] If one applies this procedure to flows into eastern Shark Slough measured by the USGS between 1939 and 1961, Figure 97 is the result. Note that the 2000 cfs design for S-355 would pass less than the average annual peak discharge for eastern Shark Slough, based upon historical data. In order to pass flood flows, the S-355 structures need a minimum of 4000 cfs (1-in-10-year flood) to a maximum of10,000 cfs (1-in-100 year) flood. (Note that the S-12 structures, designed to pass 32,000 cfs, are intended to pass approximately the 1-in-200 year event, or the "Standard Project Flood".)

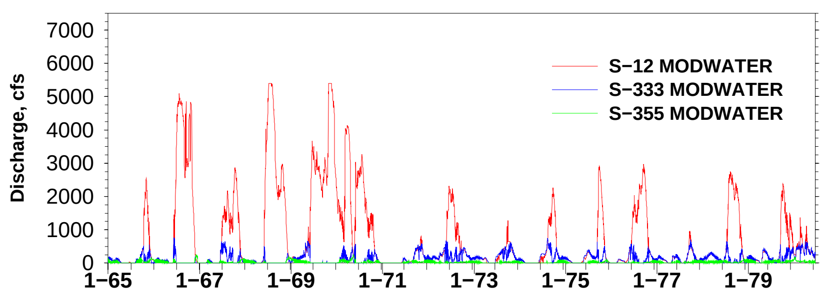
The historical data also gives additional insight into the behavior of water levels at Tamiami Trail. The discharges calculated in Figure 97 could be passed under Tamiami Trail primarily because stages got relatively high. Figure 98 is the annual maximum stage



(a) 1983 Base

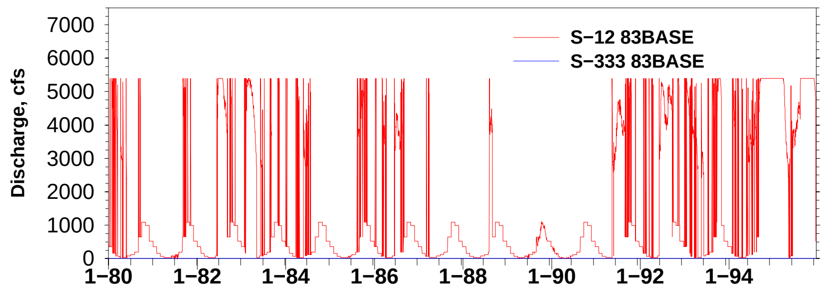


(b) Test 7 Phase I

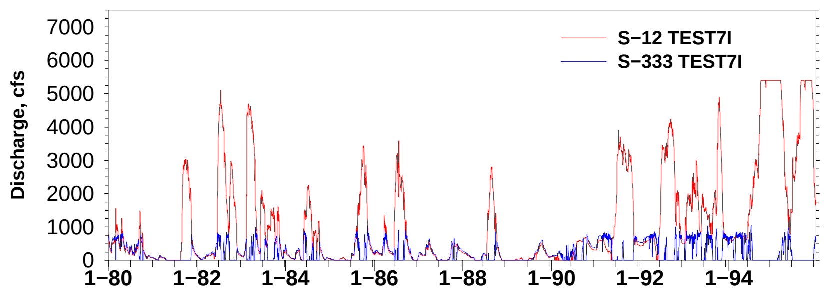


(c) Modified Water Deliveries

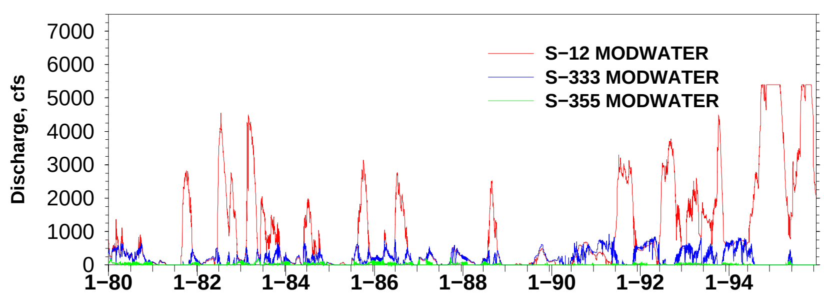
Figure 95: Daily Tamaimi Trail discharges for 1983 Base, Test 7 Phase I, and Modified Water Deliveries for 1965–1980.



(a) 1983 Base



(b) Test 7 Phase I



(c) Modified Water Deliveries

Figure 96: Daily S-12 discharges for 1983 Base, Test 7 Phase I, and Modified Water Deliveries for 1981–1995.

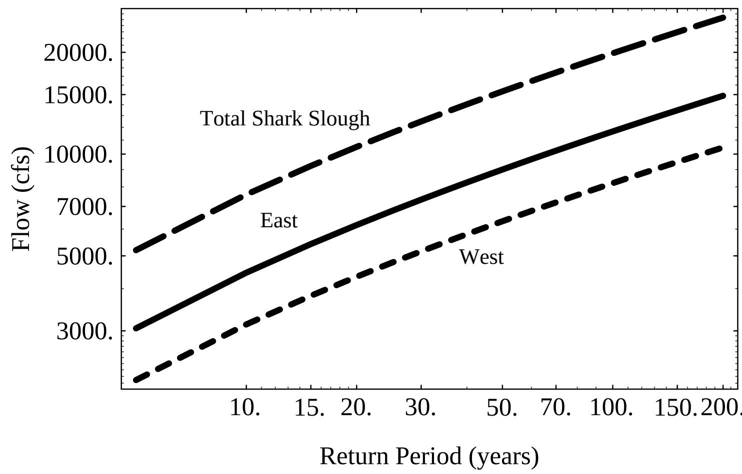


Figure 97: Flood flow frequency for eastern and western Shark Slough based upon historical data.

exceedence frequency based upon the observed data at G-618. This gage has been monitored since 1940 and the USGS used it to estimate discharges across Tamiami Trail. According to the historical data, 8.0 ft msl was the average annual maximum water level; stages exceeded 7.5 ft msl for more than 30 days for most years. The 1-in-10 year maximum stage approached 9.5 ft msl. The historical data makes an important point:

> *It is not possible to pass historical flood flows into Northeast Shark Slough without also producing historical water levels at the Tamiami Trail which produced those flood flows.*

This is simply a recognition of the physical laws governing open channel flow. To pass high flows from Tamaimi Trail to the estuaries through Shark Slough requires water levels (that is, potential energy) sufficient to overcome the drag imparted by the marsh vegetation.

4.2.2 Effects in ENP and WCA3

We look first at annual maximum stages in the southern pool of WCA-3A and in WCA-3B. Figures 99– 101 are the annual 30-day average maximum ponded depths in Water Conservation Area 3. The 30-day average maximum calculated by taking the 30-day moving average of the calculated SFWMM time series, and then extracting the annual

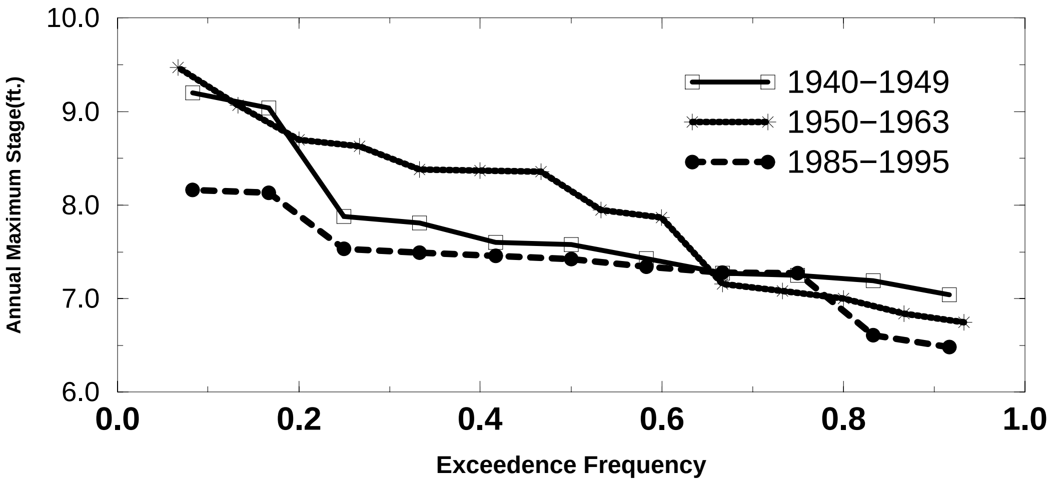


Figure 98: Annual maximum stage exceedence curves at G-618, based upon historical data.

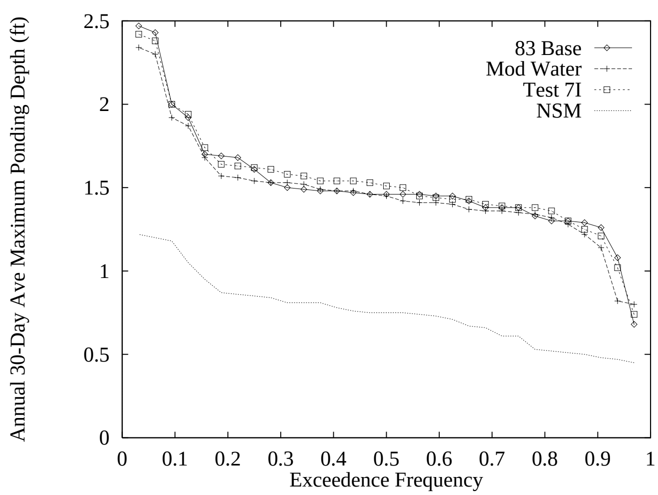


Figure 99: Annual exceedence frequency for the 30-day average maximum ponded depth for Southern WCA 3A (Indicator Region 14).

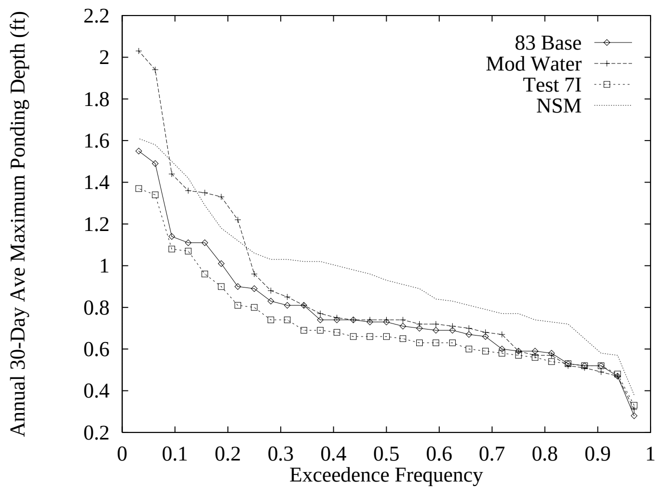


Figure 100: Annual exceedence frequency for the 30-day average maximum ponded depth for West WCA-3B (Indicator Region 15).

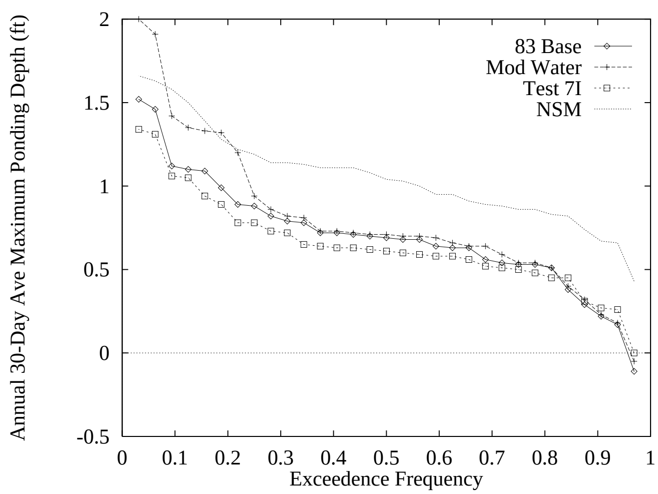


Figure 101: Annual exceedence frequency for the 30-day average maximum ponded depth for East WCA-3B (Indicator Region 16).

maximum stage. The measure indicates sustained flooding, and should give an insight into the potential for tree island effects.

The simulations estimate little effect on the southern WCA-3A stages; frequency of maximum ponding levels are very similar between the 1983 Base, Modified Water Deliveries, and Test 7 Phase I. However, the effects in WCA-3B are dramatically different. During wet years with under Modified Water Deliveries, WCA-3B is flooded to extremely deep levels, far exceeding even NSM conditions. It is very likely that these extremely deep, sustained flooding levels could result in adverse affects to the tree islands in WCA-3B.

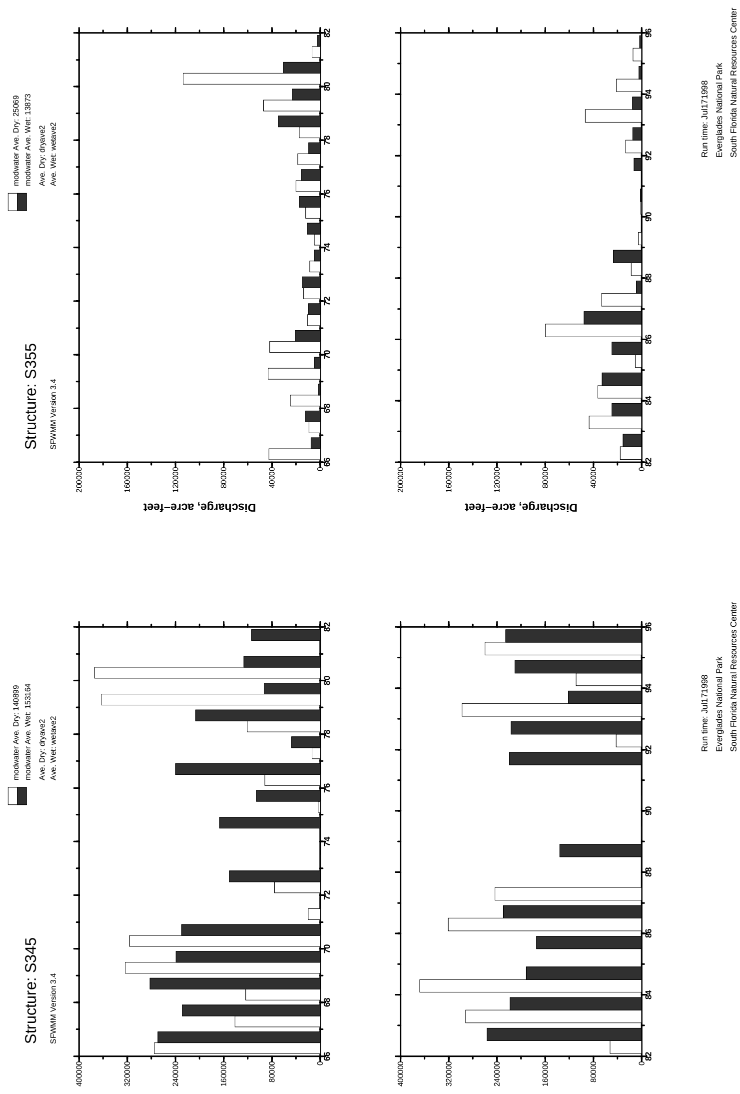
The source of the dramatic increase in WCA-3B water levels is the difference between S-345 inflows and S-355 outflows (Figure 102). During wet periods, inflows can exceed 300,000 acre-ft per year, while outflows are almost zero. The net result of a Tamiami Trail constraint is that S-345 inflows are trapped in WCA-3B and not passed into Northeast Shark Slough. That is, regulatory releases that would have been passed through the S-12 structures are instead routed in WCA-3B. But instead of being passed into Northeast Shark Slough, the L-29 constraint effectively impounds the water in WCA-3B.

The fact that the S345 flows are not passed into Northeast Shark Slough is shown by the 30-day average maximum water levels shown in Figure 103. Northeast Shark Slough shows an increase in maximum depths between Modified Water Deliveries and the 1983 Base as well as Test 7 Phase I. However, hydroperiods and annual minimum stages are roughly similar between Modified Water Deliveries and Test 7 Phase I. That is, Modified Water Deliveries is more slightly more effective at passing the wet season flows into Northeast Shark Slough than today's operations, but does not substantially increase the hydroperiods or dry season water levels.

Given this information on the Modified Water Deliveries as well as the GDM results, we see three possible operational strategies for this Project during wet conditions:

- Remove the L-29 constraint, allowing the Tamiami Trail to flood. This will reduce flooding damages in WCA-3B, improve Northeast Shark Slough, and western Shark Slough.

- Retain an L-29 constraint, allowing no damage to Tamaimi Trail. This will help western Shark Slough, severely damage WCA-3B, and have some small benefit for Northeast Shark Slough.



(a) S-345 flows

(b) S-355 flows

Figure 102: Seasonal S-345 inflows and S-355 outflows from WCA-3B.

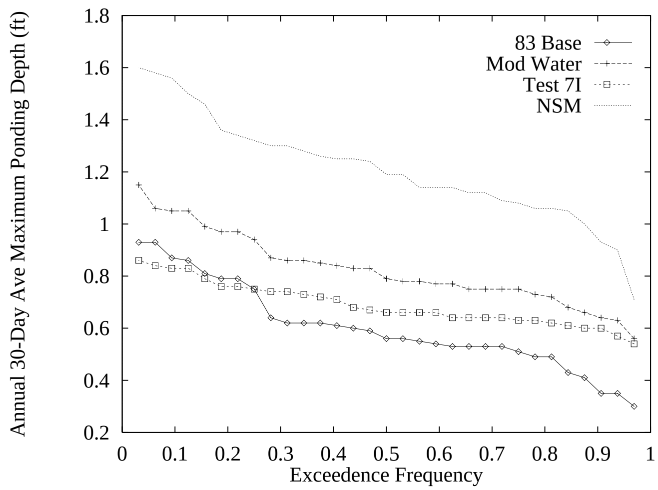


Figure 103: Annual exceedence frequency for the 30-day average maximum ponded depth for Northeast Shark Slough (Indicator Region 11).

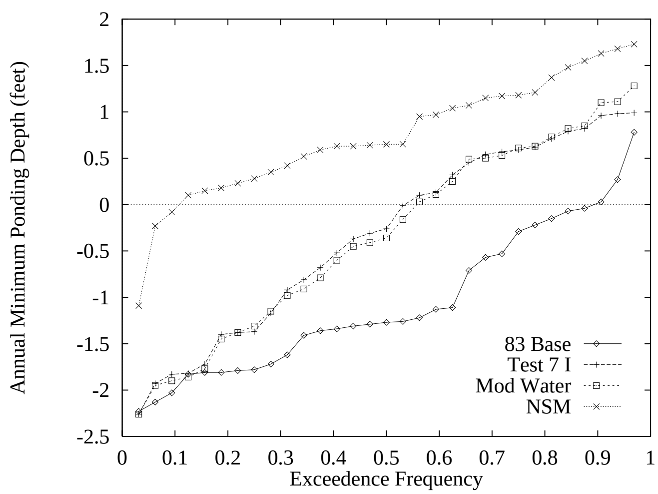


Figure 104: Annual exceedence frequency for the minimum ponded depth for Northeast Shark Slough (Indicator Region 11).

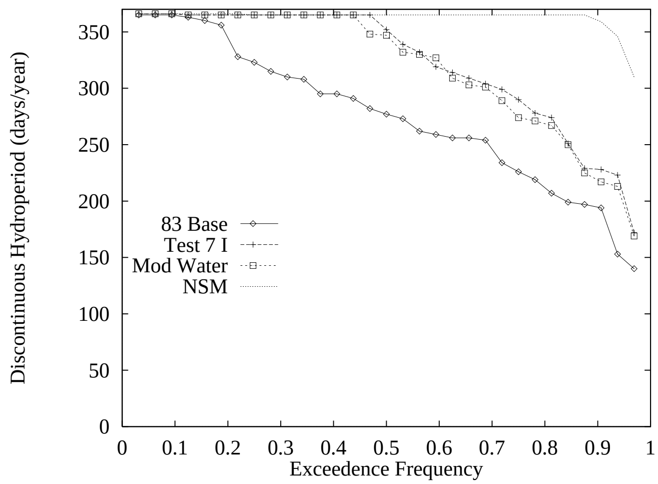


Figure 105: Annual hydroperiod exceedence frequency for Northeast Shark Slough (Indicator Region 11).

- Not operate S-345, S-333, and S-345 during wet periods. This does not result in damage to WCA-3B or Tamaimi Trail, but does not change the current problems in western Shark Slough and Northeast Shark Slough.

4.2.3 Flood Mitigation

One of the major components of the Modified Water Deliveries Project is flood mitigation for the 8.5 Square Mile Area (8.5 SMA), shown in Figure 1 on page 3. As shown in the project description map (Figure 84), the flood mitigation component consists of two pump stations, S-357 and S-356, and a levee and canal along the western edge of the 8.5 SMA. The pump S-357 pumps out of the collector canal into L-31N. The pump S-356, located at the intersection of L-31N and Tamiami Trail, pumps into L-29 borrow canal.

In the GDM, neither S-357 and S-356 have any constraints to their operation. In this analysis, a constraint on S-356 was included. As with S-355, operation of S-356 is curtailed when the tailwater (L-29 borrow canal) reaches 7.5 ft msl. If S-333 and S-355 discharges are constrained by L-29 stages because of damage to Tamiami Trail, then it is only reasonable to apply the same constraint to S-356.

The pump S-357, designed to provide flood protection to the 8.5 SMA, does not have a constraint to pumping. The implication is that the 8.5 SMA is then the priority for flood

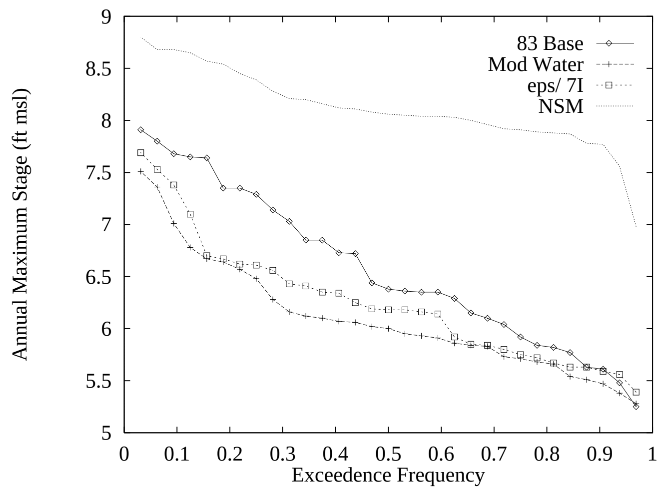


Figure 106: Annual maximum stage exceedence frequency for the 8.5 SMA.

control. Typically, since flood control is provided with gravity drainage, downstream areas are brought under control first, and control progresses upstream. Since S-173 and S-331 were intended as divide structures, the 8.5 SMA area is the furthest upstream in the L-31/C-111/C-4/C-1 drainage system. An unconstrained pumping regime at S-357 implies that the 8.5 SMA has a higher flood control priority than the rest of the L-31N basin between C-1 and C-4.

One can roughly estimated the effects of the C&SF Project for flood control by comparing estimates of pre-drainage water levels to post-C&SF Project levels. Figures 106–108 contains several measures related to the hydrologic changes in the 8.5 SMA resulting from the C&SF Project. The difference between the NSM curve and the various alternatives is a rough measure of the flood control benefit. For example, Figure 106 shows that, on the average, the maximum water levels are dropped about 2.0 ft; during wet years (1-in-10 or exceedence frequency of 0.1), the annual maximum water level is dropped about 1.5 ft. Figure 107 would indicate that, under pre-drainage conditions, water would be ponded on the surface for more than 30 days per year in 19 of 20 years (exceedence frequency of 0.95) while the 1983 Base should ponded water for more than 30 days only 1 year in 20 (exceedence frequency of 0.05). Modified Water Deliveries and Test 7 Phase I show roughly that the water levels probably do not exceed 1.2 feet below the ground for more than 30 consecutive days. Figure 108) shows the result of C&SF Project in terms of hydroperiods, or expected days that land will be flooded per year. Prior to drainage, the area was flooded 7 to 8 months per year, on the average. In 1983 Base, it takes very wet years (1-in-5 to 1-in-10) to produce any ponded water.

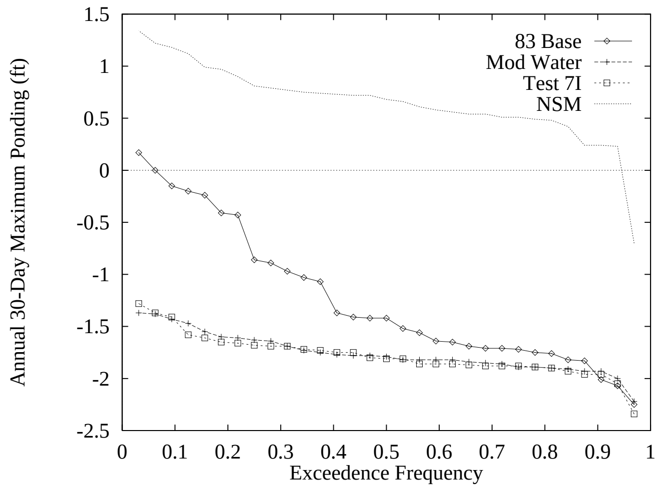


Figure 107: Annual maximum depth exceedence frequency for 30 continuous days for the 8.5 SMA.

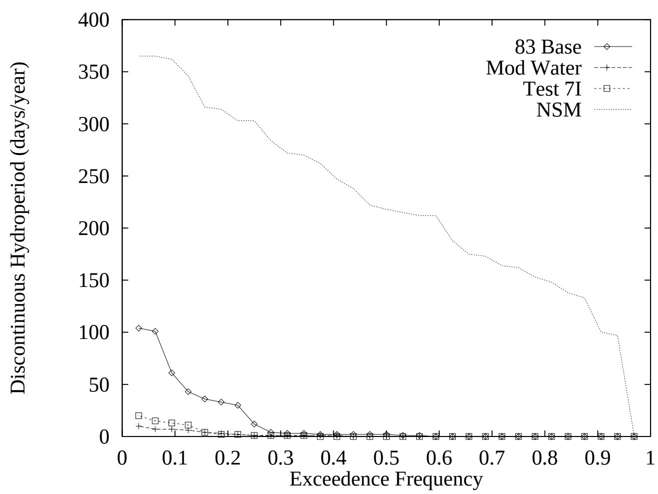


Figure 108: Hydroperiod exceedence frequency for the 8.5 SMA.

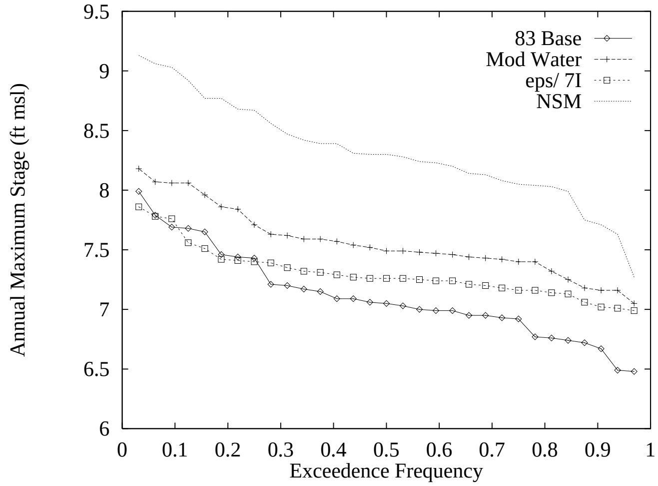


Figure 109: Annual maximum stage exceedence frequency for Northeast Shark Slough (Indicator Region 11).

A similar assessment can be made for the Everglades National Park Expansion Area, and Northeast Shark Slough. Figures 109– 111 shows the annual maximum, 30-Day continuous ponding level, and hydroperiod measures. In all cases, they indicate that water levels are increased in Modified Water Deliveries and Test 7 Phase I relative to the 1983 Base Condition, but are still far below what could be expected without the C&SF Project. Under the 1983 Base condition water levels are 1 to 1.50 feet below pre-Project conditions. The Modified Water Deliveries and Test 7 Phase I increase this to approximately 1 foot below pre-Project conditions.

The SFWMM is not the ideal tool for determining flooding impacts for a given alternative. However, it can, in a general way, give some insights into potential flood control implications for a given alternative. For example, one can compare the predicted operation for S-356 and S-357, as in Figures 112–113. Very clearly, S-356 operations are curtailed during the wettest periods (1968, 1969, 1994, 1995), while S-357 continues to operate during those same periods.

A second important indicator of the possible of flood control implications is the L-31N surface water inflow and outflow comparisons. Figures 114–115 compare structure inflows and outflows in the L-31N reach between S-335 and S-331. Note that, under Modified Water Deliveries, S-335 inflows are substantially increased, a result of ponding levels in WCA-3B, which in turn, are the result of L-29 stage restrictions. Moreover, S-356 outflows are very small in wet years, such as 1994 and 1995. In fact, for wet years (such as 1968,

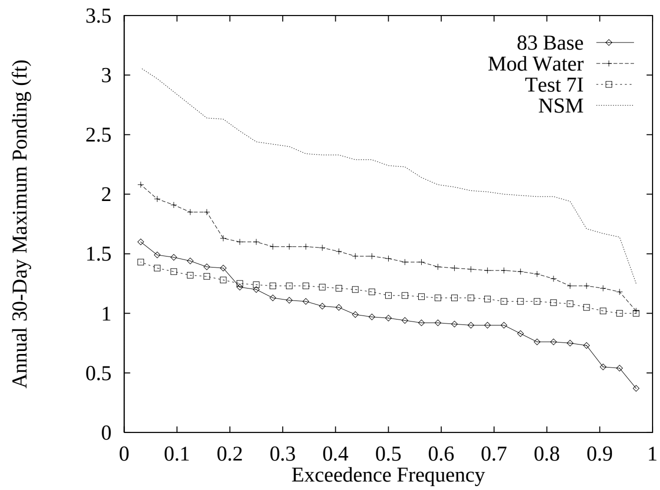


Figure 110: Annual maximum depth exceedence frequency for 30 continuous days for Northeast Shark Slough (Indicator Region 11).

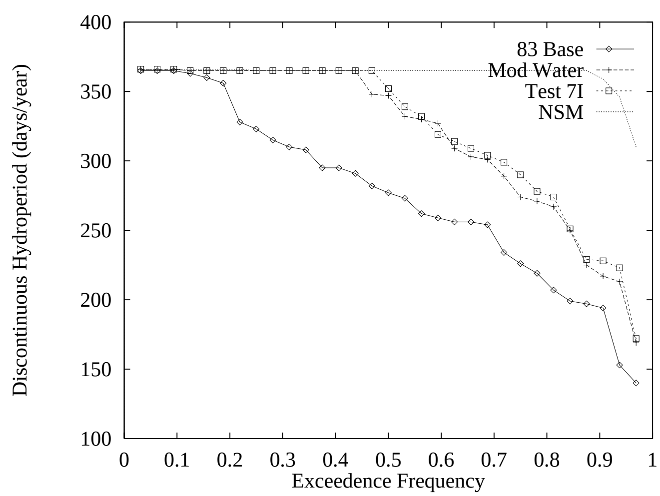


Figure 111: Hydroperiod exceedence frequency for Northeast Shark Slough (Indicator Region 11).

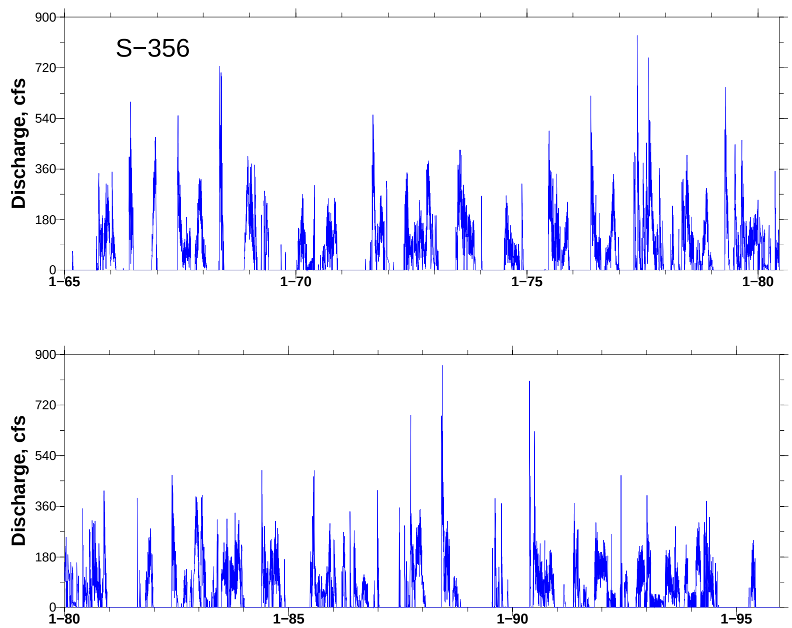


Figure 112: Daily S-356 operations for Modified Water Deliveries.

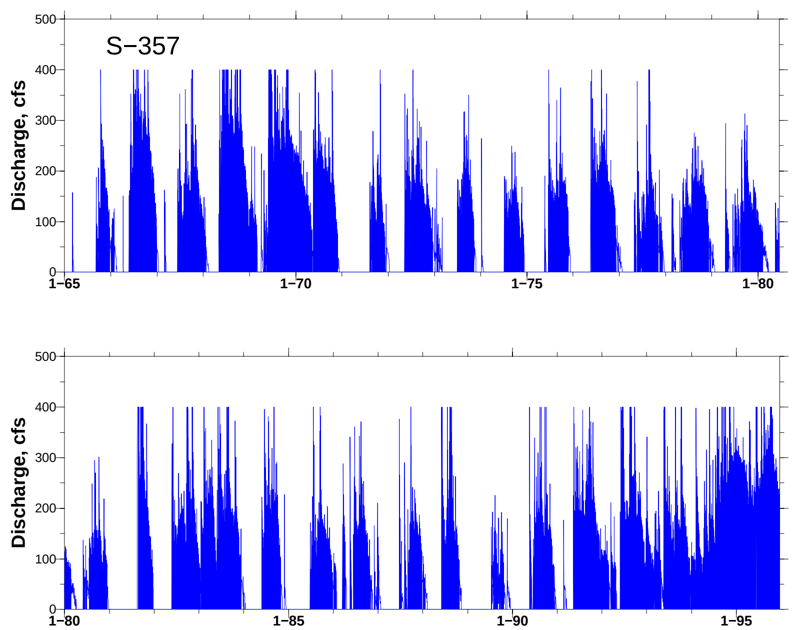
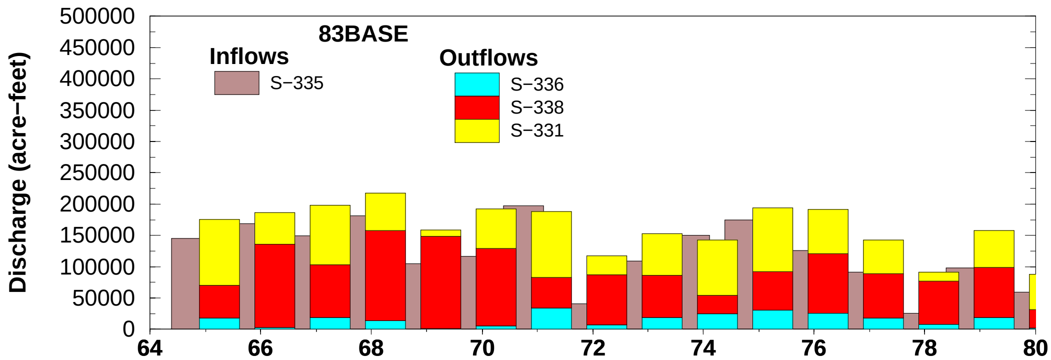
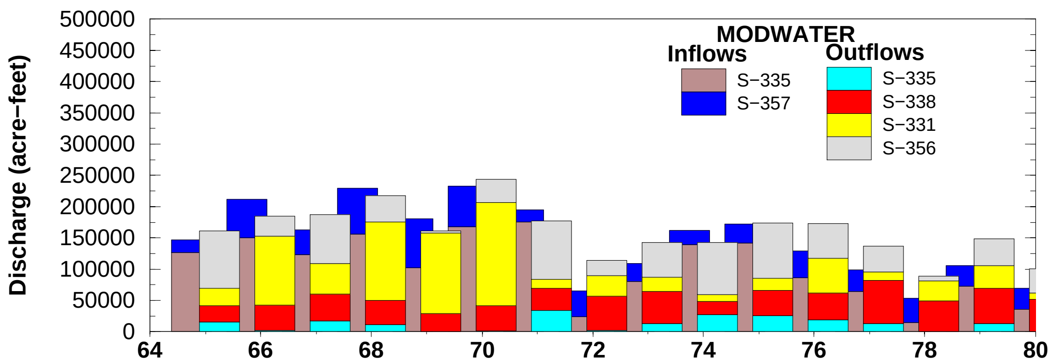


Figure 113: Daily S-357 operations for Modified Water Deliveries.

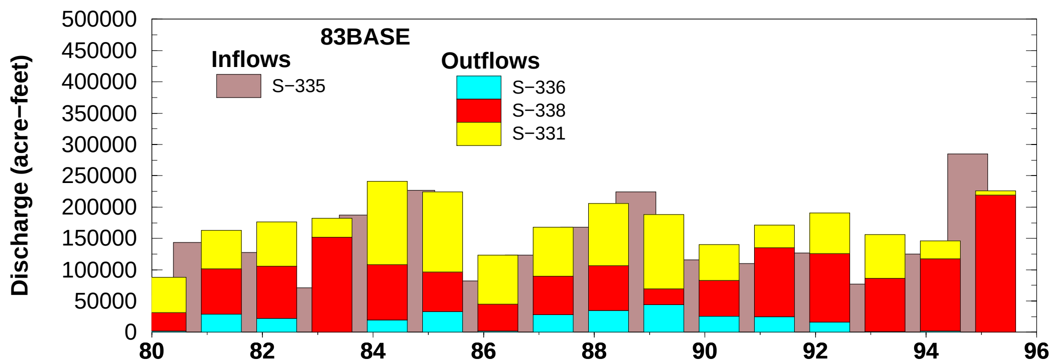


(a) 1983 Base

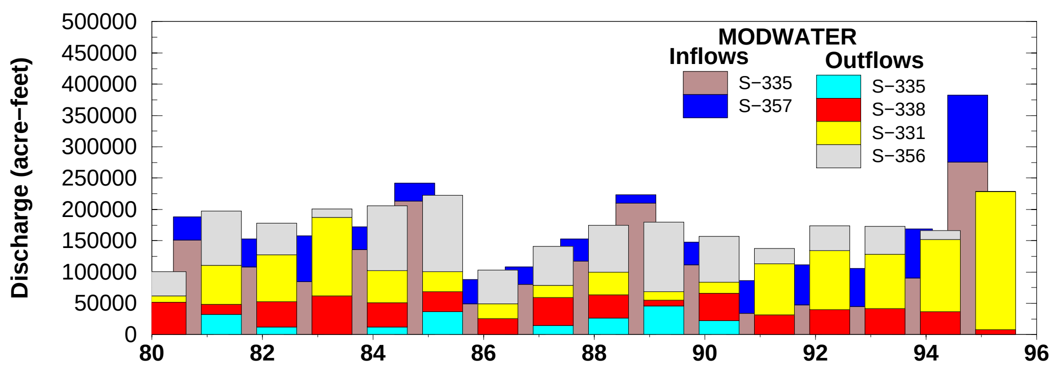


(b) Modified Water Deliveries

Figure 114: Comparison of surface water inflows and outflows for the L-31N reach between S-335 and S-331 for the years 1965–1980.



(a) 1983 Base



(b) Modified Water Deliveries

Figure 115: Comparison of surface water inflows and outflows for the L-31N reach between S-335 and S-331 for the years 1981–1995.

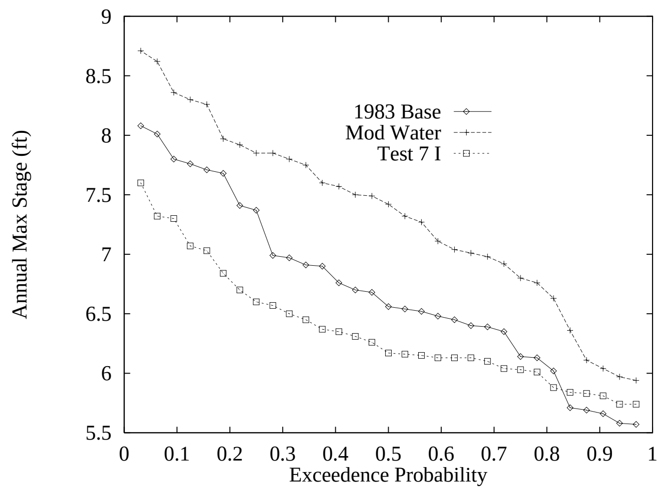


Figure 116: Annual maximum stage in L-31N reach between S-331 and S-335. Test 7 reach is between S-335 and G-211.

1969, 1970, and 1995), inflows to this reach significantly exceed outflows, indicating that during floods, the canal acts to recharge groundwater. Most likely the bulk of this excess inflow is moving as groundwater to the east.

A third indicator of possible flood control implications is the L-31N stage itself. Figure 116 shows the frequency of the annual maximum stage. Note that L-31N for Test 7 Phase I is included for reference, but is not a direct comparison. In Test 7 Phase I, the reach is from S-335 to G-211, while in the 1983 Base and Modified Water Deliveries, the reach is from S-335 to S-331. In Test 7, G-211 has an open criteria of 6.0, while in 1983 Base, S-338 has open of 5.0 feet and S-331/S-173 are used for water supply only. Because of S-357 and S-355 inflows, the annual maximum stages for Modified Water Deliveries increase by approximately 1.5 feet.

Another important indicator of the possibility for flooding is annual maximum stage. Figure 117 is the difference in average annual maximum stage between the 1983 Base and Modified Water Deliveries. Clearly visible are the lower stages in western Shark Slough and along C-102/C-103. The former is related to the lower discharges into Shark Slough, while the latter is results from the S-332A and S-332C pumps in the C-111 Project. Increased peak water levels are observed in WCA-3B, Northeast Shark Slough, Taylor Slough, lower C-111 and western Dade county. All but the former are design objectives in Modified Water and C-111 Projects. The higher stages in western Dade county result from the combination increases seepage from WCA-3B, S-357 pumping, constraints to S-356, and S-331 operation.

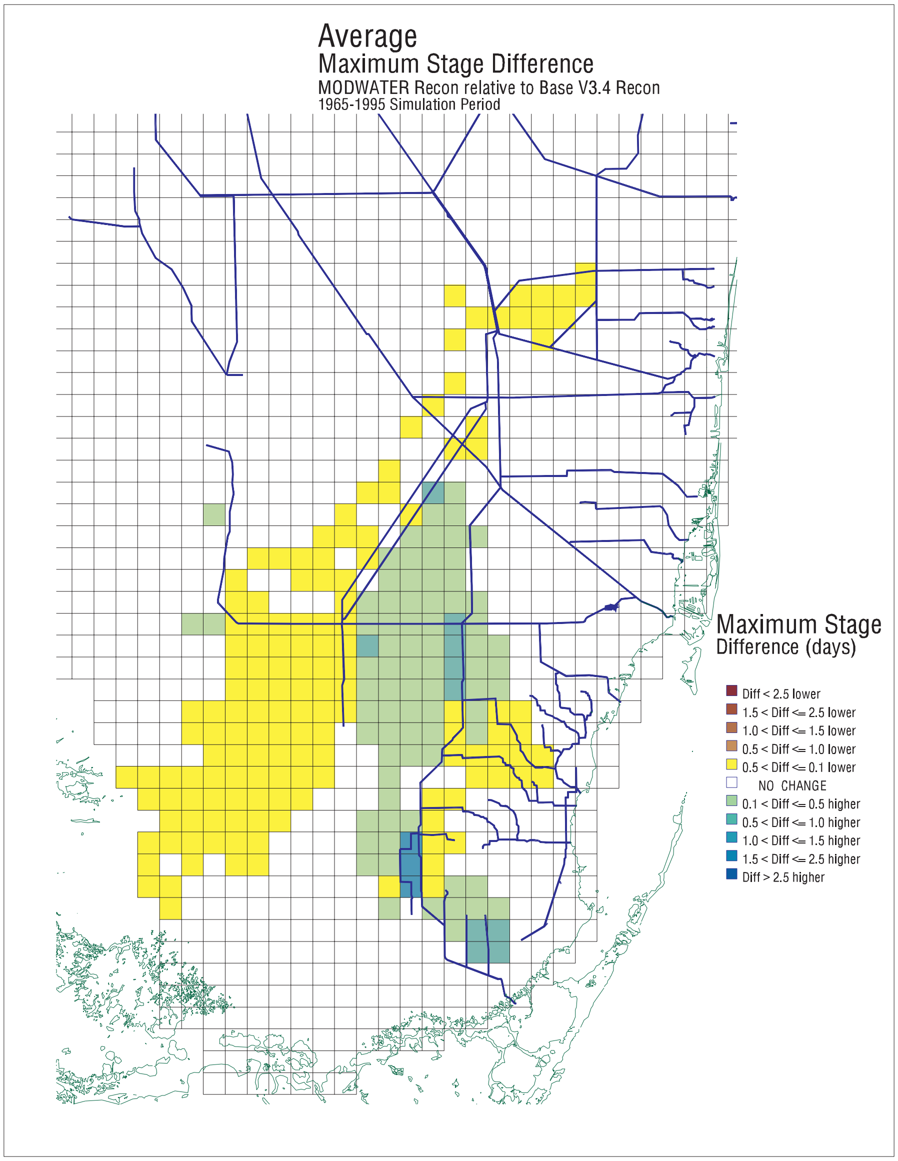


Figure 117: Difference in the average maximum stage between the 1983 Base and Modified Water Deliveries.

The above analysis is predicated on using S-331 for water supply only (as designed and as specified in the C-111 GRR) and an L-29 constraint to S-355 and S-356 operations. These are the two factors which lead to an analysis which differs from the GDM. However, the combination of this analysis and that presented in the GDM leads to the following range of options for providing flood mitigation to the 8.5 SMA

- Construct and operate authorized Project and remove the L-29 constraint, likely causing Tamiami Trail damage, but which is consistent with the GDM.
- Construct and operate the authorized Project and retain L-29 constraint, likely causing tree island damage to WCA-3B and a higher risk of flooding to western Miami-Dade county.
- Construct and operate the authorized Project, retain the L-29 constraint, but remove the S-331 flood control operation, resulting in large interbasin transfers of flood waters into south Miami-Dade county and C-111.
- Revisit aspects of the Modified Water Deliveries Project.

4.3 Effects on Endangered Species

4.3.1 Cape Sable Seaside Sparrow

As with the analysis of Experimental Water Deliveries, we use as a performance measure the number of nesting days available in each of the habitats as an indirect indicator of effects of the proposed action on the Cape Sable seaside sparrow. Figures 118–123 are measures of the probability of having a given number of nesting days in a between March 15 and June 1.

According to Figure 118, Modified Water Deliveries significantly increases the number of nesting days for subpopulation A, resulting in conditions drier than the 1983 Base, Test 7 Phase I, and NSM. Similarly, the C-111 Project is also responsible for significantly increasing the number of nesting days for subpopulation D , resulting in conditions much drier than the 1983 Base, Test 7 Phase I, and NSM. Both of these can be considered beneficial with respect to the sparrow.

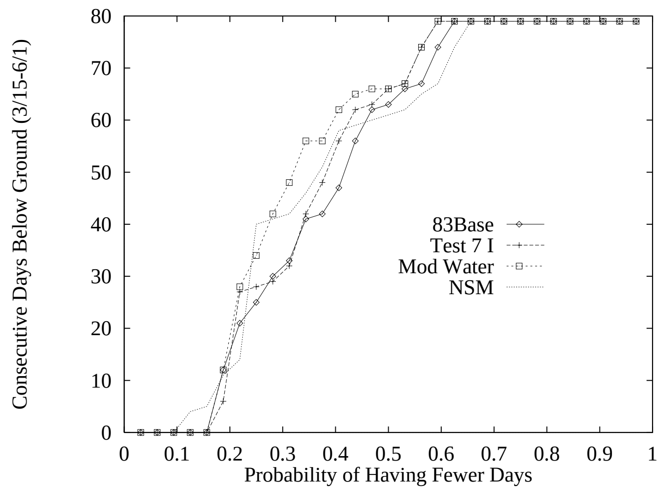


Figure 118: Return frequencies for number of consecutive days when water levels are below ground between March 15 and June 1 for sparrow habitat A.

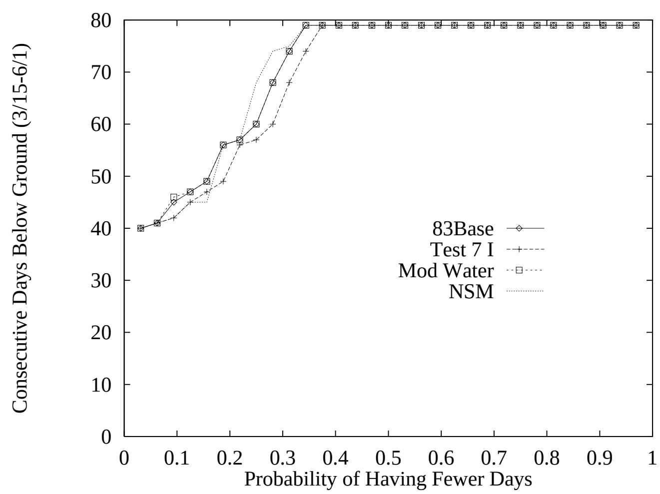


Figure 119: Return frequencies for number of consecutive days when water levels are below ground between March 15 and June 1 for sparrow habitat B.

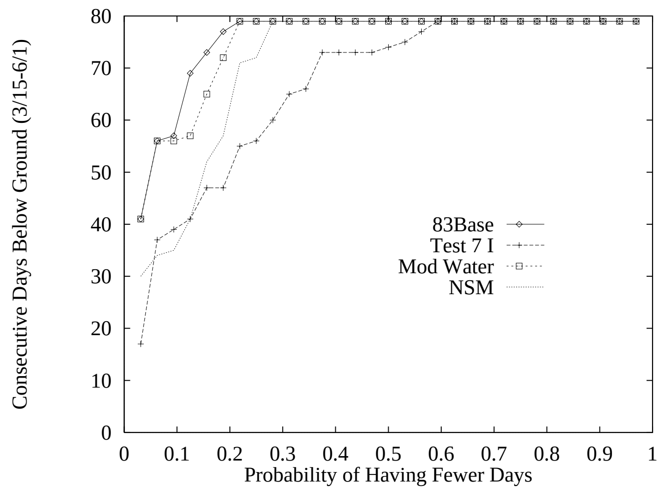


Figure 120: Return frequencies for number of consecutive days when water levels are below ground between March 15 and June 1 for sparrow habitat C.

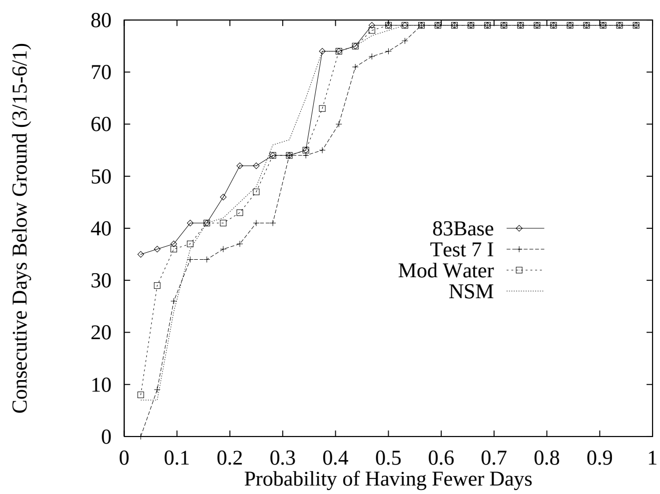


Figure 121: Return frequencies for number of consecutive days when water levels are below ground between March 15 and June 1 for sparrow habitat D.

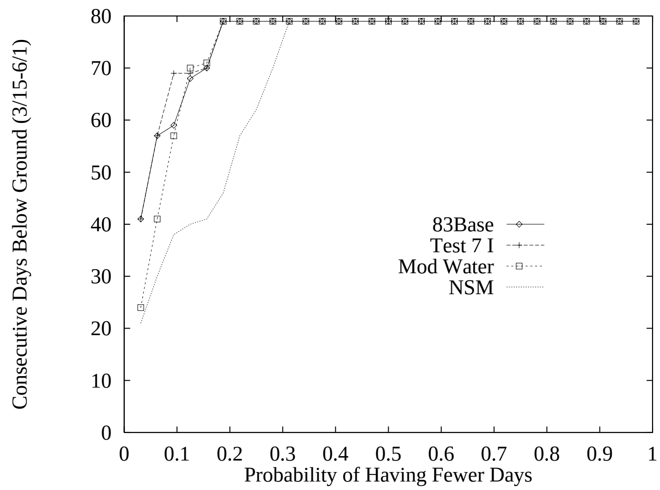


Figure 122: Return frequencies for number of consecutive days when water levels are below ground between March 15 and June 1 for sparrow habitat E.

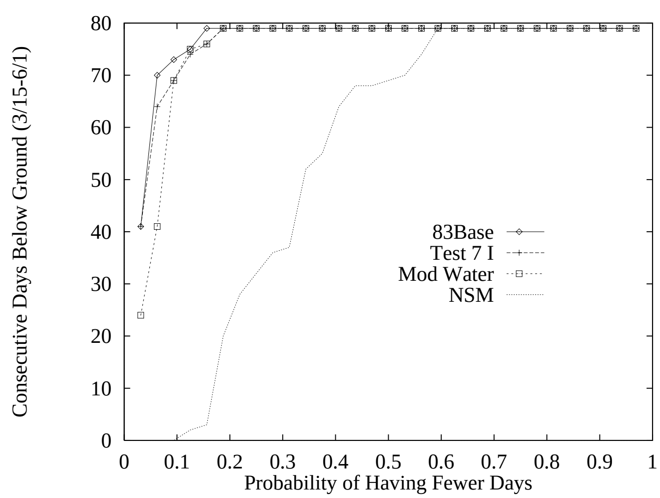


Figure 123: Return frequencies for number of consecutive days when water levels are below ground between March 15 and June 1 for sparrow habitat F.

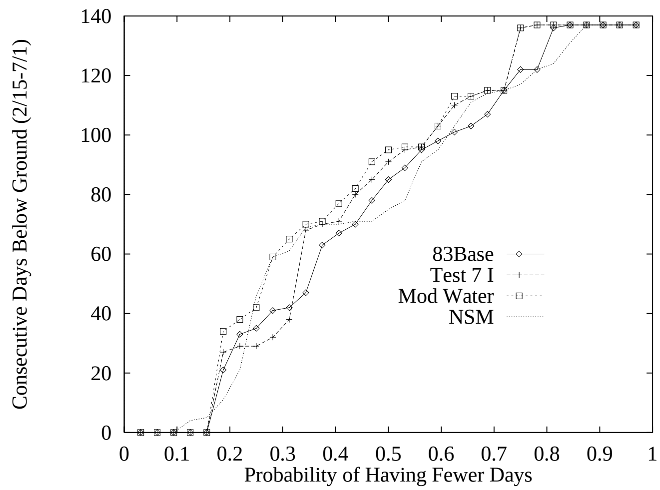


Figure 124: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat A.

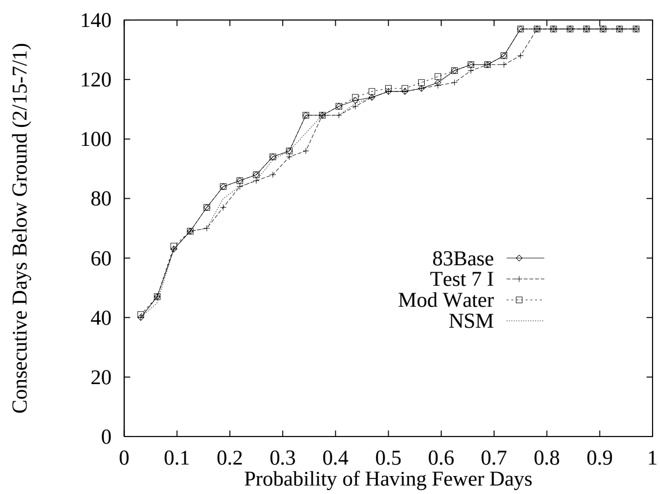


Figure 125: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat B.

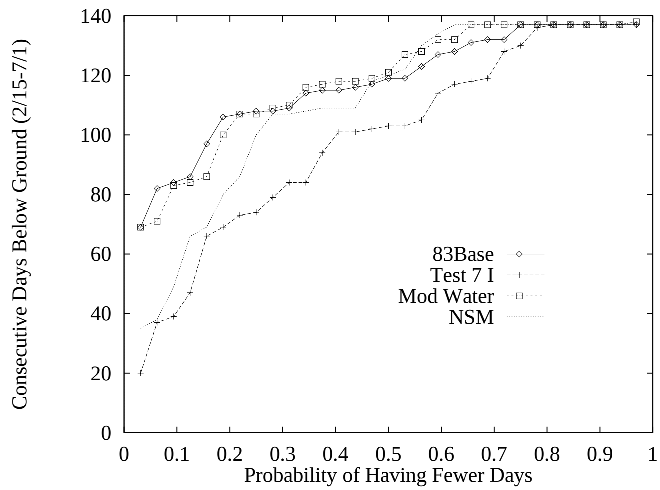


Figure 126: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat C.

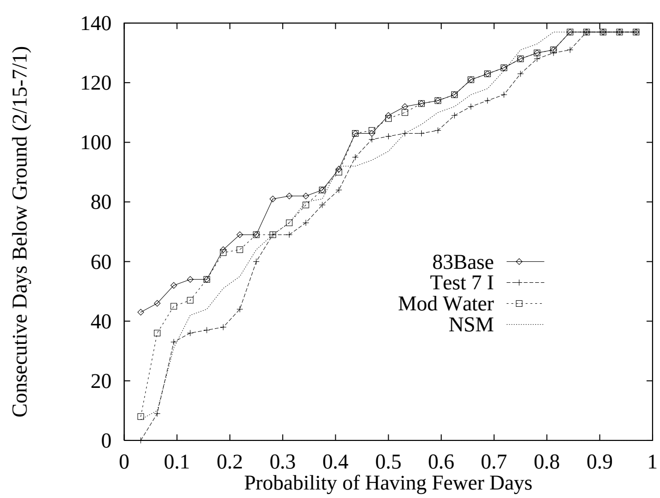


Figure 127: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat D.

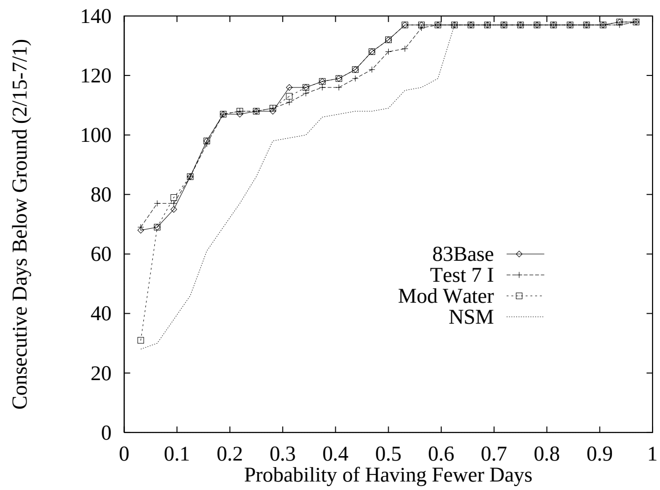


Figure 128: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat E.

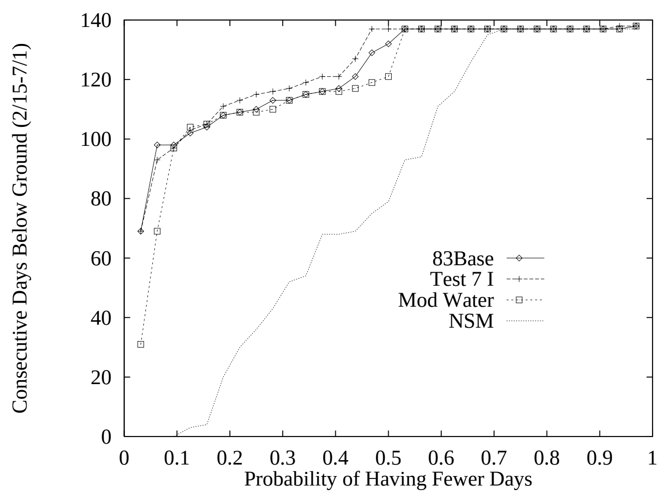


Figure 129: Return frequencies for number of consecutive days when water levels are below ground between February 15 and July 1 for sparrow habitat F.

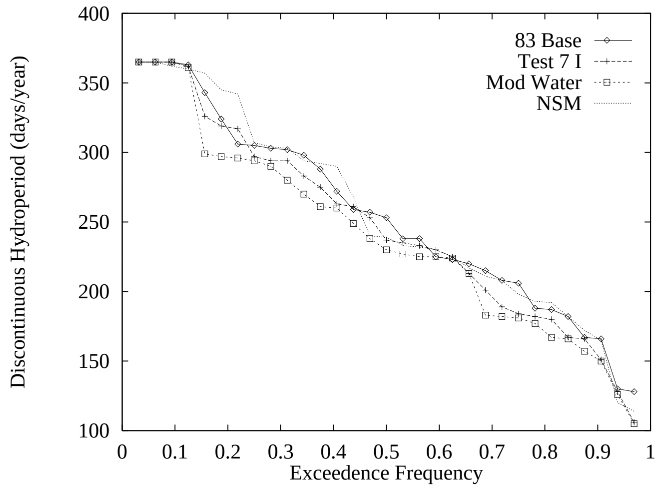


Figure 130: Hydroperiod frequencies for sparrow habitat A.

The C-111 Project also matches the 1983 Base condition hydroperiods in those habitats that are currently overdrained, such as C, E, and F. As shown in Figures 130–dh2Fmw, hydroperiods in subpopulation C, E, and F increase relative to Test 7 Phase I, but show roughly similar results as the 1983 Base.

Therefore, one could conclude that the C-111 Project should improve conditions in the sparrow habitats relative to Test 7 Phase I, and not worsen conditions relative to the 1983 Base Condition.

Neither the C-111 nor the Modified Water Deliveries Project have any obvious effect on the Ingraham Highway subpopulation, subpopulation B.

The modeling done here also predicts no adverse impacts to subpopulation C. However, the C-111 Project was modeled here more or less as Test 7 Phase II rules for S-332D. Armentano *et al.* [1995] report vegetation shifts and Pimm [1997] show population declines for this subpopulation under those similar operation rules. Given this inconsistency, it would be more prudent to base the predicted effects on subpopulation C on the Corps's MODBRANCH model.

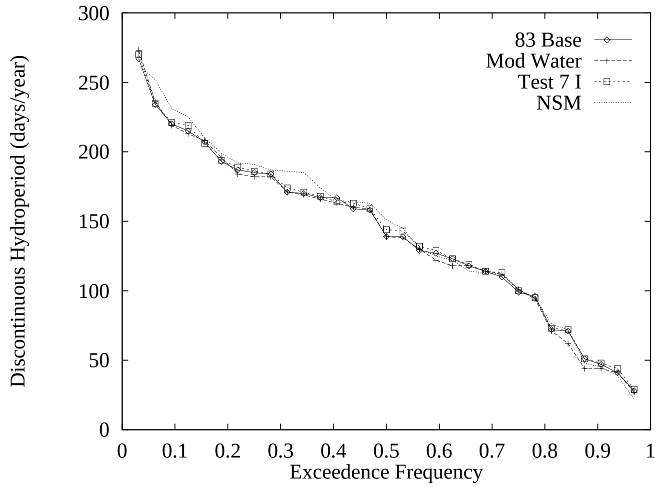


Figure 131: Hydroperiod frequencies for sparrow habitat B.

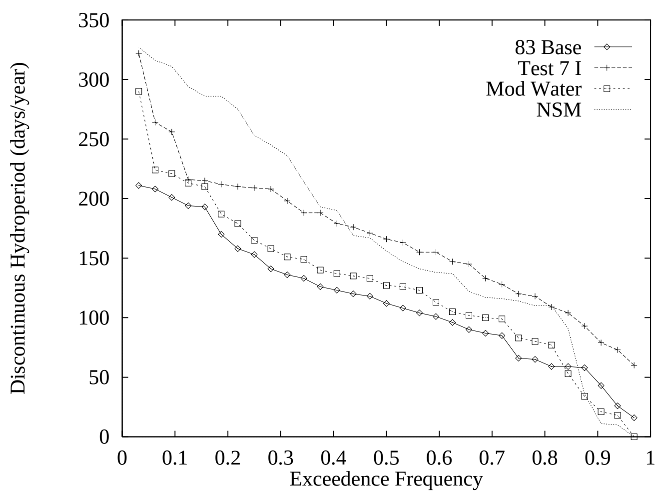


Figure 132: Hydroperiod frequencies for sparrow habitat C.

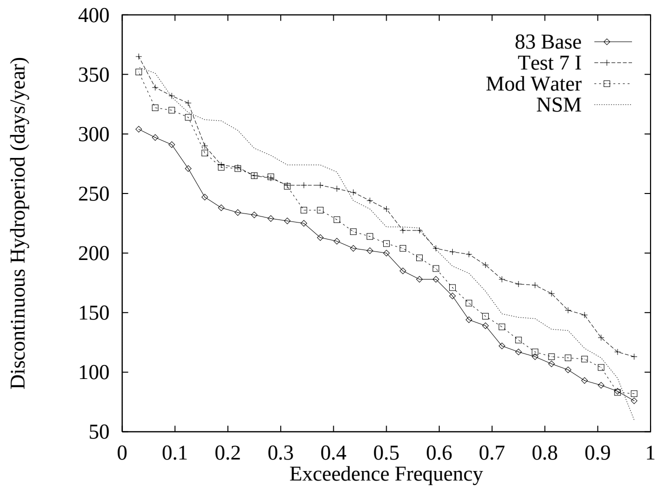


Figure 133: Hydroperiod frequencies for sparrow habitat D.

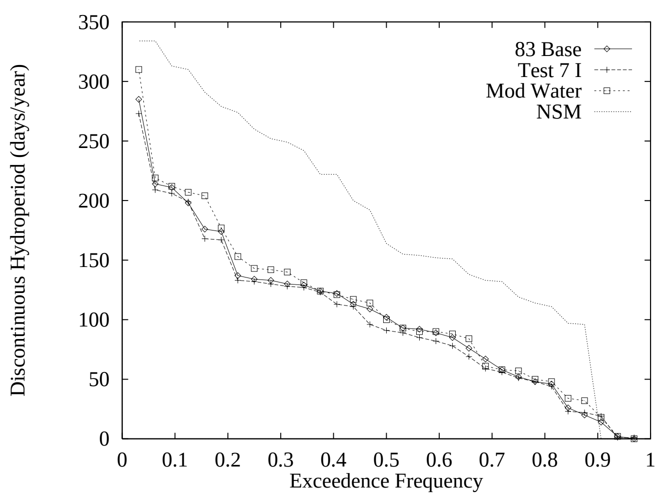


Figure 134: Hydroperiod frequencies for sparrow habitat E.

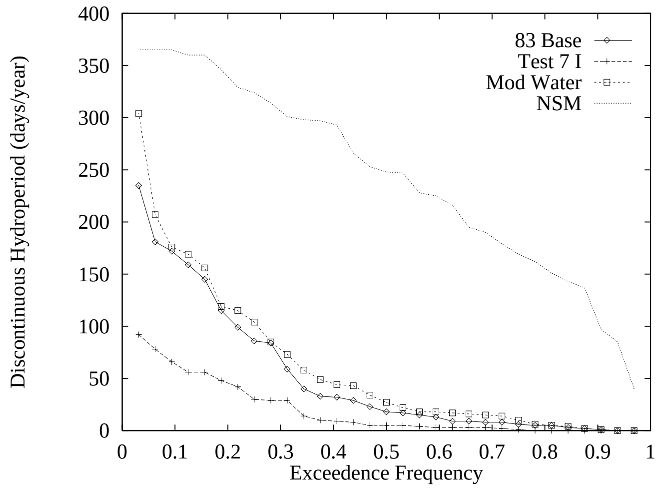


Figure 135: Hydroperiod frequencies for sparrow habitat F.

4.3.2 Wood Stork

The possible effects of the Modified Water Deliveries Project on wood storks are estimated by applying the same performance measure as above to simulated conditions under Test 7 Phase I and to the 1983 Base Conditions. Table 17 on page 105 also shows the results of this evaluation. According to this evaluation Modified Water Deliveries provides average uninterrupted hydroperiods that are 22 - 31% of the NSM values. For average duration of uninterrupted hydroperiods across the two indicator regions considered (IR Mean), Modified Water Deliveries performs no better than Test 7 Phase I (see Table 4 on page 66) and 17% worse than 83 Base Conditions. The simulations suggest that for average annual flow volumes into the Shark Slough estuaries, Modified Water Deliveries provide 53% of NSM values compared to 58% under Test 7 Phase I and 62% under the 83 Base Conditions. For Taylor Slough, Modified Water Deliveries is predicted to provide 93% of NSM values compared to 125% under Test 7 Phase I and 87% under the 83 Base. For flow volumes into the estuaries, Modified Water Deliveries performs no better than the current conditions and 9% worse than the 83 Base Conditions in Shark Slough, and lower than the current conditions and only slightly better than the 83 Base in Taylor Slough. In Taylor Slough, this would be viewed as a favorable condition, as it should not be assumed that a flow for Taylor Slough that averages well above NSM is benefiical for storks. It may be just as detriemental ecologically as a flow average flow in Shark Slough (Ogden, pers. comm.) Overall, when hydroperiods and flow volumes are considered together (Total Score), Modified Water Deliveries is predicted to provide a 14% decline in habitat conditions compared

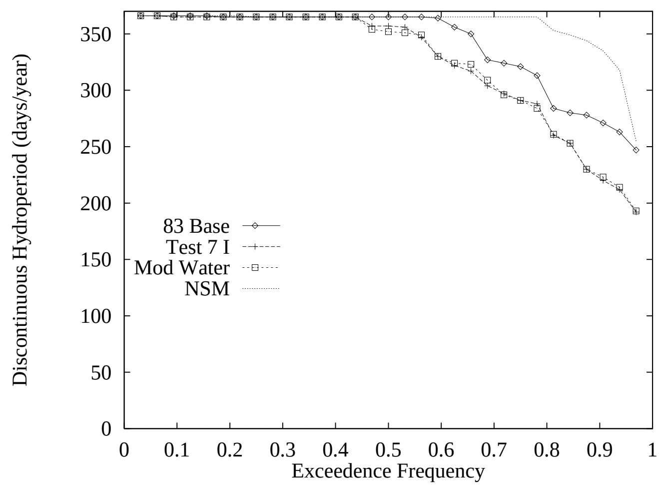


Figure 136: Annual hydroperiod exceedence frequency for south western Shark Slough (Indicator Region 9).

to current conditions, and an 6% decline in habitat conditions compared to 83 Base. For only Shark Slough, when hydroperiods and flow volumes are considered together (Total Score), Modified Water Deliveries is predicted to be no different than current conditions and to provide a 11% decline in wood stork foraging habitat conditions in the region of the traditional estuarine stork nesting colonies compared to 83 Base.

4.3.3 Crocodile and Manatee

The possible effects of Modified Water Deliveries on crocodiles and manatees are estimated by comparing the salinity ranges expected to Test 7 Phase I and to the 1983 Base Condition. The Crocodile Habitat Suitability graphs for Modified Water Deliveries are shown in Figures 54–58 on pages 69–71. As above, the desired condition is to slightly increase the percent of months in the low salinity category and reduce the percent of months in the high salinity category. According to these simulations Modified Water Deliveries slighly increase the percent of months in the high salinity category and increases the percent of months in the lower salinity category compared to Test 7 Phase I and remains slighly worse than the conditions predicted for the 1983 Base. According to these simulations, Modified Water Deliveries produces slightly less suitable crocodile and manatee habitat than under Test 7 Phase I and apparently below that provided by the 1983 Base Condition.

The frequency of annual flow volumes towards Florida Bay is shown in Figure 138. The

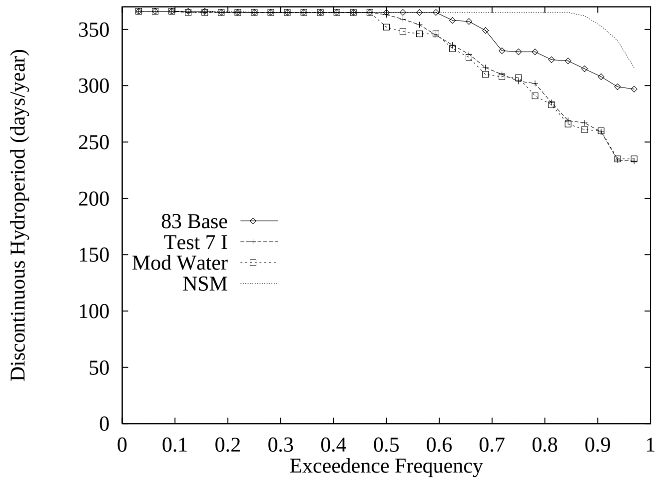


Figure 137: Annual hydroperiod exceedence frequency for central Shark Slough (Indicator Region 10).

desired condition is to provide flows that are similar to those predicted by the Natural Systems Model. According to these simulations freshwater inflows are expected to be about the same towards Florida Bay under Modified Water Deliveries as they are under the 83 Base, and less than that provided by Test 7 Phase I. For Florida Bay, Modified Water Deliveries approaches NSM flow values. According to these simulations Modified Water Deliveries might be expected to produce about an equal amount of suitable crocodile and manatee habitat compared to the 1983 Base Condition, slightly less than predicted by NSM, and much less than predicted by Test 7 Phase I. With respect to Test 7, these results appear inconsistent with the predicted salinity categories used to determine crocodile habitat suitability. The crocodile habitat suitability measure is suspect in this evaluation probably due to its reliance on the gauge NP-33. This gauge is more of a regional index and is not physically or causally related to the basins of northeastern Florida Bay. Figure 139 shows the distribution of mean monthly flow volumes towards Florida Bay. The desired condition is to match the pattern of monthly flow distribution as predicted by NSM. According to these simulations Modified Water Deliveries delivers significantly less flow than Test 7 Phase I during the wet season and early fall, and slightly less during the dry season months. NSM flow volumes are matched or slightly exceeded during the early wet season and fall short during the critical hatchling survival months of September - December. Monthly flow volumes under Modified Water Deliveries are about equal to 1983 Base Conditions, with a slight increase over the 83 Base during the fall. These reduced flows during the fall months suggest that Modified Water Deliveries might be expected to produce much less suitable crocodile habitat than under Test 7 Phase I, and equal to or slightly more than expected

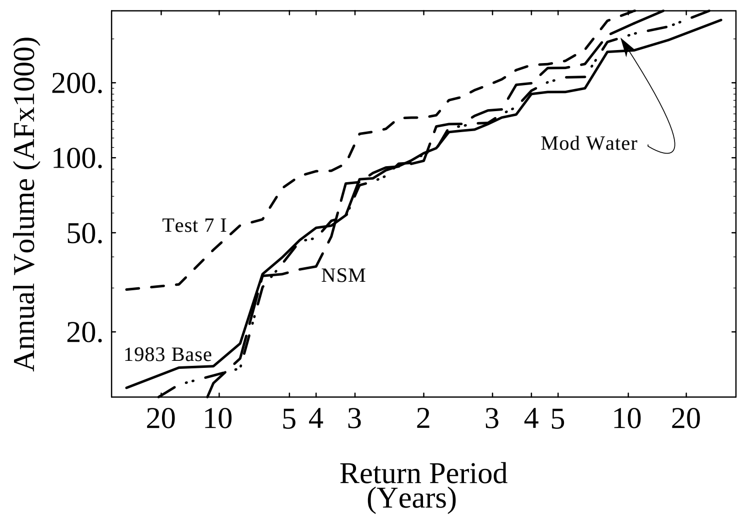


Figure 138: Frequency of annual freshwater inflows towards Florida Bay.

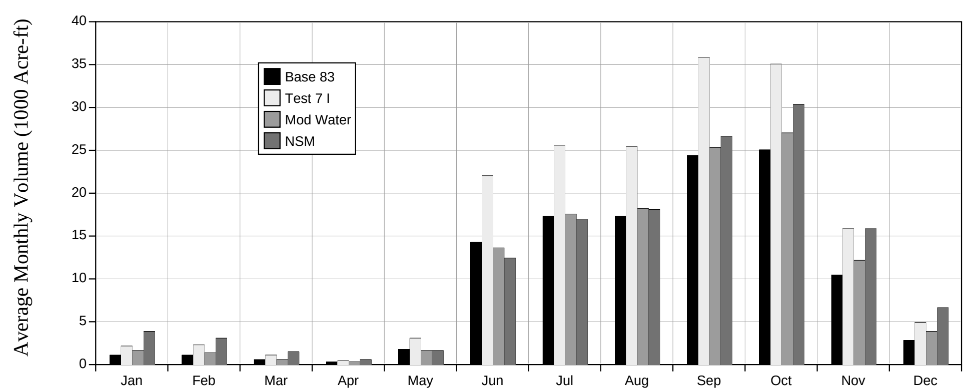


Figure 139: Average monthly volumes into Florida Bay.

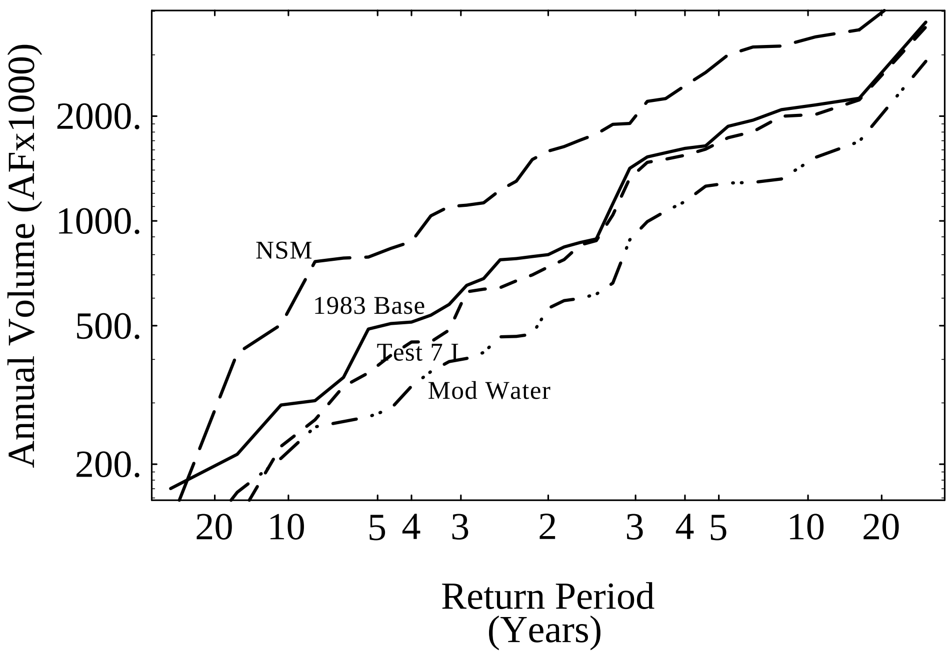


Figure 140: Frequency of annual freshwater inflows into the Shark Slough estuaries.

from the 83 Base.

Figure 140 shows the frequency of input of annual flow volumes towards Shark Slough estuaries. The freshwater in flows under Modified Water Deliveries less than Test 7 Phase I and the 83 Base, and much less than predicted for NSM. According to these simulations Modified Water Deliveries might be expected to produce less suitable crocodile and manatee habitat in the western Everglades estuaries as Test 7 Phase and the 83 Base and much less than NSM.

Figure 58 shows the Crocodile Habitat Suitability graph for the North River Mouth. As with the basins of northeastern Florida Bay, the desired condition is to increase the percent of months in the low salinity category and reduce the percent of months in the high salinity category. According to these simulations Modified Water Deliveries has little or no effect on the percent of months in the low salinity category or the percent of months in the high salinity category compared to Test 7 Phase I. Compared to the 1983 Base Condition, Modified Water Deliveries decreases the percent of months in the low salinity category and increases the percent of months in the high salinity category. According to these simulations Modified Water Deliveries might be expected to produce about the same amount of crocodile

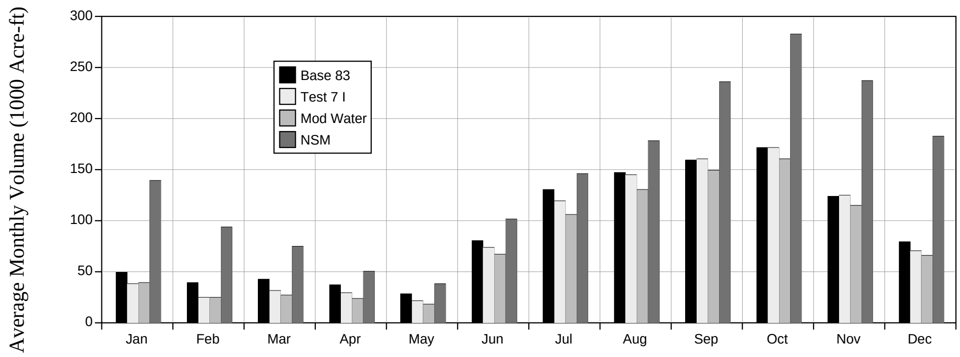


Figure 141: Average monthly volumes into Shark Slough.

and manatee habitat in the western Everglades estuaries as Test 7 Phase I, and slightly less habitat as than the 1983 Base Condition. The Crocodile Habitat Suitability measure for North River Mouth appears more or less with the results expected from predicted annual flow volumes towards Shark Slough.

Figure 141 shows the distribution of mean monthly flow volumes into Shark Slough. As with northeastern Florida Bay, the desired condition is to match the pattern of monthly flow distribution as predicted by NSM. According to these simulations monthly flows under Modified Water Deliveries are lower than or equal to Test 7 Phase I, and lower than the 83 Base. Modified Water Deliveries, Test 7 Phase I, and the 83 Base all share a similar pattern of monthly flow volumes that is significantly different than that predicted by NSM. All three scenarios produce flows that are slightly less than NSM during the early wet season but with a pattern of increasing flows briefly similar to NSM. However, during the critical crocodile hatchling survival months of September - December and during the dry season, flow volumes for Modified Water Deliveries, Test 7 Phase I, and the 83 Base all fall significantly short of NSM. Flows under NSM rise sharply during the critical crocodile hatchling survival months of August - October, compared to the three scenarios. A steady increase in favorable salinity ranges for crocodile hatchlings would be expected. Flows under Modified Water Deliveries, Test 7 Phase I, and the 83 Base for these months are nearly flat. During the dry season, flows under Modified Water Deliveries, Test 7 Phase I, and the 83 Base, are also nearly flat and do not show any evidence of the lag flows characteristic of the natural system. These reduced flows during the fall months, that appear to peak earlier and at significantly lower volumes than NSM, suggest that Modified Water Deliveries, Test 7 Phase I, and the 83 Base might be expected to produce much less suitable crocodile habitat in the western Everglades estuaries than NSM, with Modified Water Deliveries and Test 7 Phase I producing the least. Figure 141 also illustrates that Modified Water Deliveries does not provide any improvement, compared to Test 7 Phase I and the 83 Base, in the pattern of flow volumes to the Shark Slough estuaries that might be considered favorable to crocodiles.

Summary

According to the Restudy's Crocodile Habitat Suitability measure, Modified Water Deliveries produces slightly less suitable crocodile and manatee habitat in northeastern Florida Bay than under Test 7 Phase I and the 1983 Base Condition, and provides much less than that predicted by NSM. However, according to predicted flow volumes into northeastern Florida Bay, Modified Water Deliveries might be expected to produce much less suitable crocodile and manatee habitat than predicted by Test 7 Phase I, about an equal amount compared to the 1983 Base Condition, slightly less than predicted by NSM. With respect to Test 7, these results appear somewhat inconsistent with the predicted salinity categories used to determine crocodile habitat suitability. The Restudy's crocodile habitat suitability measure is suspect in this evaluation probably due to its reliance on the gauge NP-33.

Reduced flows into northeastern Florida Bay during the critical hatchling survival months (Aug - Dec) suggest that Modified Water Deliveries might be expected to produce much less suitable crocodile habitat than under Test 7 Phase I, equal to or slightly more than expected from the 83 Base, and equal to or less than that expected from NSM. It should be noted that under Modified Water Deliveries the distribution of flows is skewed to the east closer to the C-111 drainage area than Taylor Slough. Flows directed through Taylor Slough can potentially provide more and better crocodile habitat.

According to the Restudy's Crocodile Habitat Suitability measure for North River Mouth, Modified Water Deliveries might be expected to produce about the same amount of suitable crocodile and manatee habitat in the western Everglades estuaries than under Test 7 Phase I, slightly less habitat as expected from the 1983 Base Condition, and much less than NSM.

According to predicted flow volumes into Shark Slough estuaries, Modified Water Deliveries might be expected to produce less suitable crocodile and manatee habitat in the western Everglades estuaries as Test 7 Phase I and the 83 Base, and much less than NSM. The Crocodile Habitat Suitability measure for North River Mouth appears more or less consistent with the results expected from predicted annual flow volumes into Shark Slough.

Reduced flows into the Shark Slough estuaries during the critical hatchling survival months (Aug - Dec), that appear to peak earlier and at significantly lower volumes than NSM, suggest that Modified Water Deliveries, Test 7 Phase I, and the 83 Base might be expected to produce much less suitable crocodile habitat in the western Everglades estuaries than NSM, with Modified Water Deliveries and Test 7 Phase I producing the least.

4.3.4 Snail Kite

To assess the possible effects of the Modified Water Deliveries Project on snail kites the same methods as described above were applied. According to this evaluation method Tables 28 to 36 suggest that under Modified Water Deliveries the conditions for snail kites remain favorable, similar to those predicted for the 83 Base and existing conditions (Test 7), in Basin 14, Southern 3A, and Western 3B. Under Modified Water Deliveries conditions are slightly less favorable for snail kites in Western 3A compared to the 83 Base and Test 7. Except for Western 3A, it appears there would be little or no significant change, between Modified Water Deliveries, 83 Base, and Test 7, in the areas currently used by nesting kites. Under Modified Water Deliveries conditions in Eastern 3B remain the same as those predicted for the 83 Base and Test 7, unfavorable. From Northeast Shark Slough to SW Shark Slough the results are mixed and conclusions somewhat elusive. In Northeast Shark Slough, Modified Water Deliveries provides significant hydrological improvement over the 83 Base. With respect to kites, however, it appears there would be little or no signficant change in Northeast Shark Slough between Modified Water Deliveries and current conditions. Northeast Shark Slough remains largely unfavorable to kites under Modified Water Deliveries. According to this evaluation method, Table 34 suggests marginally favorable conditions generally remain in Basin 10 Mid-Shark Slough under Modified Water Deliveries, similar to conditions predicted under Test 7. Conditions in Basin 10, however, are worse for kites under Modified Water Deliveries when compared to the 83 Base. In SW Shark Slough (Basin 9), Modified Water Deliveries provides about the same conditions as Test 7 and worse conditions than those predicted for the 83 Base.

Looking only at the frequency of drying events, Table 36 suggests that under Modified Water Deliveries only Indicator Region 14, Southern 3A Snail Kite Habitat , and Western 3B are predicted to provide suitable or marginal conditions for snail kites. These conditions are similar to or slightly worse than those predicted for Test 7. Elsewhere under Modified Water Deliveries conditions remain generally unfavorable, similar to those predicted for Test 7. According to the frequency of drying events, under Modified Water Deliveries conditions for snail kites remain borderline suitable and generally unchanged in the Southern 3A Snail Kite Habitat Basin and improve yet remain marginal in Western 3B compared to 83 Base. And conditions in Western 3A worsen under Modified Water Deliveries compared to the 83 Base becoming unsuitable because the area drys out too frequently. Elsewhere under Modified Water Deliveries conditions are considered unsuitable because drying events occur too frequently. The conditions in Eastern 3B southward to SW Shark Slough are about the same as those predicted for the 83 Base. Overall, considering the two evaluation methods, it appears that in general Modified Water Deliveries has little or no significant effect on existing hydrologic conditions in the following areas used by nesting kites: Basin 14 - Southern WCA 3A and Southern 3A Snail Kite Habitat Basin. The adjacent area, Basin 15 - Western WCA 3B, also appears to be relatively unaffected. In Western 3A, an area also used by nesting kites, conditions under Modified Water Deliveries are predicted to be slightly worse than existing conditions. Compared to existing conditions, Modified Water Deliveries appears to provide no significant improvement in potential kite habitat from Eastern 3B southward to SW Shark Slough.

The hydrologic information presented in Tables 28 to 36 relevant to the Modified Water Deliveries simulations are presented in Appendix A.3. Figures 212–234. Figure 221. Figures 222– 227 are a measure of the stage at which ponded levels are below for 30 consecutive days. Figures 228– 234 are a measure of the frequency of the 1 day minimum ponded levels.

Snail Kite Monitoring

According to Bennetts [pers. com, 1998] Recent research has indicated that changes in hydrology as a result of Everglades restoration activities are likely to result in changing spatial distribution of Snail Kites. However, a demographic response (e.g., changes in survival and/or reproduction) may result if relatively long-hydroperiod areas (e.g., $> 90\%$) are substantially reduced within the South Florida Ecosystem. Only the latter response would potentially jeopardize the viability of the Florida Snail Kite population. Thus, it is essential that any monitoring program for Snail Kites through the restoration process be capable of distinguishing these two responses. At the current time radio telemetry and mark-recapture methods offer the most feasible means of accomplishing this goal, with mark-recapture being most cost effective. Because the annual Snail Kite survey does not account for detectability, it is not capable of distinguishing these effects and these behavioral and demographic responses are highly confounded [Bennetts *et al.*, 1998].

Western WCA-3A Snail Kite Habitat				
Indicator	NSM	1983 Base	Test 7 Phase I	Modified Water Deliveries
Median Hydroperiod (days/year)	**358**	365	360	**355**
Fraction of years hydroperiod less than 310 days	**0.39**	**0.35**	**0.35**	**0.35**
Fraction of years there is a drying event	**0.63**	0.55	**0.61**	**0.65**
Fraction of years there is a drying event lasting 30 days or longer	0.42	**0.45**	0.42	0.42
Fraction of years there is a drying event before May	0.55	0.54	**0.55**	**0.58**

Table 28: Summary of selected measures related to the snail kite for the Western 3A Snail Kite Habitat. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Southern WCA-3A Snail Kite Habitat				
Indicator	NSM	1983 Base	Test 7 Phase I	Modified Water Deliveries
Median Hydroperiod (days/year)	365	365	365	365
Fraction of years hydroperiod less than 310 days	0.28	**0.07**	0.10	0.11
Fraction of years there is a drying event	0.53	0.34	0.33	0.34
Fraction of years there is a drying event lasting 30 days or longer	0.35	0.19	0.19	0.19
Fraction of years there is a drying event before May	0.49	0.18	0.18	0.16

Table 29: Summary of selected measures related to the snail kite for southern Snail Kite habitat. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 14: Southern WCA-3A				
Indicator	NSM	1983 Base	Test 7 Phase I	Modified Water Deliveries
Median Hydroperiod (days/year)	365	365	365	365
Fraction of years hydroperiod less than 310 days	0.32	**0.07**	0.07	0.08
Fraction of years there is a drying event	0.51	0.26	**0.23**	0.24
Fraction of years there is a drying event lasting 30 days or longer	0.39	**0.10**	**0.10**	0.13
Fraction of years there is a drying event before May	0.48	**0.09**	**0.11**	**0.10**

Table 30: Summary of selected measures related to the snail kite for Indicator Region 14: Southern WCA-3A. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 15: Western WCA-3B				
Indicator	NSM	1983 Base	Test 7 Phase I	Modified Water Deliveries
Median Hydroperiod (days/year)	**359**	365	365	365
Fraction of years hydroperiod less than 310 days	0.30	0.33	0.23	0.32
Fraction of years there is a drying event	0.58	0.44	0.40	0.41
Fraction of years there is a drying event lasting 30 days or longer	0.39	0.35	0.35	0.35
Fraction of years there is a drying event before May	0.52	0.35	0.30	0.34

Table 31: Summary of selected measures related to the snail kite for Indicator Region 15- West WCA-3B. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 16: Eastern WCA-3B				
Indicator	NSM	1983 Base	Test 7 Phase I	Modified Water Deliveries
Median Hydroperiod (days/year)	365	**272**	**300**	**280**
Fraction of years hydroperiod less than 310 days	0.19	**0.71**	**0.59**	**0.66**
Fraction of years there is a drying event	0.50	**0.92**	**0.80**	**0.92**
Fraction of years there is a drying event lasting 30 days or longer	0.32	**0.81**	**0.65**	**0.74**
Fraction of years there is a drying event before May	0.40	**0.79**	**0.65**	**0.70**

Table 32: Summary of selected measures related to the snail kite for Indicator Region 16- East WCA-3B. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 11: Northeast Shark Slough				
Indicator	NSM	1983 Base	Test 7 Phase I	Modified Water Deliveries
Median Hydroperiod (days/year)	365	**277**	**352**	**347**
Fraction of years hydroperiod less than 310 days	**0.06**	**0.74**	**0.39**	**0.42**
Fraction of years there is a drying event	**0.14**	**0.95**	0.58	0.61
Fraction of years there is a drying event lasting 30 days or longer	**0.10**	**0.81**	**0.48**	**0.52**
Fraction of years there is a drying event before May	**0.03**	**0.88**	**0.56**	**0.56**

Table 33: Summary of selected measures related to the snail kite for Indicator Region 11- Northeast Shark Slough. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 10: Mid Shark Slough				
Indicator	NSM	1983 Base	Test 7 Phase I	Modified Water Deliveries
Median Hydroperiod (days/year)	365	365	363	**352**
Fraction of years hydroperiod less than 310 days	**0.06**	0.14	0.32	**0.35**
Fraction of years there is a drying event	**0.19**	0.45	0.55	0.57
Fraction of years there is a drying event lasting 30 days or longer	**0.10**	0.32	0.42	**0.45**
Fraction of years there is a drying event before May	**0.03**	0.29	0.45	0.50

Table 34: Summary of selected measures related to the snail kite for Indicator Region 10- Mid- Shark Slough. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Indicator Region 9: SW Shark Slough				
Indicator	NSM	1983 Base	Test 7 Phase I	Modified Water Deliveries
Median Hydroperiod (days/year)	365	365	**357**	**352**
Fraction of years hydroperiod less than 310 days	0.09	0.25	**0.37**	**0.36**
Fraction of years there is a drying event	0.25	0.47	0.60	0.60
Fraction of years there is a drying event lasting 30 days or longer	0.13	0.39	**0.48**	**0.45**
Fraction of years there is a drying event before May	0.14	0.40	**0.56**	**0.56**

Table 35: Summary of selected measures related to the snail kite for Indicator Region 9- SW Shark Slough. Bold values indicate values outside of the range of values predicted under current conditions (Test 7 Phase I) in the following areas: Western 3A snail kite habitat, Southern 3A Snail Kite habitat, and IR 14 (Southern WCA-3A).

Basin	NSM	83 Base	Test 7 Phase I	Modified Water Deliveries
Western 3A Snail Kite Habitat	0.63	0.55	0.61	0.65
IR 14- Southern WCA-3A	0.51	**0.26**	**0.23**	**0.24**
Southern 3A Snail Kite Habitat	0.53	*0.34*	**0.33**	*0.34*
IR 15-West WCA-3B	0.58	*0.44*	*0.40*	*0.41*
IR 16-East WCA-3B	0.50	0.92	0.80	0.92
IR 11-Northeast Shark Slough	0.14	0.95	0.58	0.61
IR 10-Mid-Shark Slough	*0.19*	*0.45*	0.55	0.57
IR 9- SW Shark Slough	**0.25**	*0.47*	0.60	0.60

Suitability Legend

Condition	Range[a]	Type font
Unsuitable	$f <= 0.16$	Roman
Marginal	$0.16 < f <= 0.19$	*Italic*
Suitable	$0.20 < f <= 0.33$	**Bold**
Marginal	$0.33 < f <= 0.49$	*Italic*
Unsuitable	$f > 0.49$	Roman

[a] Where f is the exceedence frequency of a dryout.

Table 36: Summary by basin of the fraction of years there is a drying event at or below ground surface, classified as suitable, marginal, or unsuitable.

All recent evidence suggests [Rodgers and Stangel, 1996; Bennetts and Kitchens, 1997] that the Florida Population of Snail Kites is one contiguous population which shifts in distribution and habitat use throughout central and south Florida. Consequently, it is essential for the geographic scope of this project to include the entire range of Snail Kites in Florida. Attempts to monitor local aggregations of Snail Kites do not provide reliable information about the Florida population as a whole [Bennetts, pers. com., 1998].

The perception over the past three decades has been that the occurrence of drought implied a demographic catastrophe for Snail Kites in which survival and reproduction of kites plummet. Previous management recommendations have consequently focused on "freezing" or stabilizing specific hydrologic conditions in large-scale impounded wetland units to provide critical habitat for the maintenance of this species. This is counter to the natural dynamics under which these wetland systems evolved and we believe may have long-term negative impacts on the habitat. Thus, it is imperative that we have an understanding of the demographic response of Snail Kites during such conditions, and the only means of accomplishing this goal is to have a valid monitoring program in place at the time of occurrence. Widespread droughts occur in South and Central Florida at a frequency of approximately every 10 years. We have had a mark-recapture program in place for 7 years. Thus, a mark-recapture program would enable both monitoring of the kite population through any restoration effort, but would simultaneously allow for estimation of critical parameters in the event of a widespread regional drought [Bennetts, pers. com., 1998].

Summary

For possible effects of Modified Water Deliveries on snail kites the following geographic areas were examined: SW Shark Slough (IR 9), Mid Shark Slough (IR 10), Northeast Shark Slough (IR 11), South WCA-3A (IR 14), West WCA-3B (IR 15), East WCA-3B (16), the western side of WCA-3A, and the extreme southern end of WCA-3A.

The following hydrologic conditions relevant to the snail kite were examined for NSM, 83 Base, existing conditions (as represented by Test 7 Phase I), two Alternatives, and Modified Water Deliveries: hydroperiod frequencies, annual minimum ponding depth, annual 30 - day minimum ponding depth, and the frequency and duration of dry-outs occurring between January and April.

This evaluation relied on Tables 28–35, which summarize the selected hydrologic measures related to the snail kite for each of the geographic areas evaluated and for each water management scenario considered, and identify favorable and unfavorable conditions.

Also used in the evaluation is Table 36, which is a summary by basin, for each of the water management scenarios considered, of the fraction of years there is a drying event at or below ground surface classified as suitable conditions, marginal conditions, or unsuitable conditions for snail kites.

According to these simulations Modified Water Deliveries has little or no effect on existing hydrologic conditions in southern WCA-3A. This suggests that southern WCA-3A will continue to provide favorable snail kite habitat, distributed (in space and time) in a manner similar to today.

A continuation of existing conditions also suggests that Modified Water Deliveries does little or nothing to improve (add to) the network of habitats available to snail kites. Bennetts and Kitchens [1997] believe that it is the extent of available habitat throughout a vast network that enables kites to persist. Bennetts and Kitchens [1997] hypothesize, and anecdotal evidence strongly supports, that a key to the long term survival of snail kites is to have some areas available when the inevitable and periodic fluctuations in the quality of other habitats occur. Bennetts and Kitchens [1997] describe the concept by the analogy of not having all of your eggs in one basket and that the baskets in which your eggs are in vary in quality over time.

4.4 Summary of Effects of Modified Water Deliveries/C-111 on Endangered Species

We have the following conclusions with respect to the Cape Sable seaside sparrow:

- Modified Water Deliveries increases the window of nesting opportunity for the Cape Sable seaside sparrow.
- An increase in nesting opportunity for the Cape Sable seaside sparrow will likely improve the long-term viability of the western subpopulation.

- However, the benefits to the Cape Sable seaside sparrow came at the expense of WCA-3B, which shows the potential for damage to tree islands.
- The C-111 Project has no effect on subpopulations A, and is not designed to have an effect on subpopulation A.
- The C-111 Project has beneficial effects to subpopulations C, D, E, and F relative to Test 7 Phase I.
- The C-111 Project is about the same as the 1983 Base for subpopulations C, E, and F.
- The effects of the C-111 Project on subpopulation C are not known, and depend upon the configuration of the Frog Pond detention area, which has not yet been designed. The supplemental C-111 GRR will have to be re-evaluated to determine the effects on the sparrow.

We have the following conclusions with respect to the wood stork:

- For Shark Slough, Modified Water Deliveries is predicted to be no different or slightly worse than current conditions and to provide about a 11% decline in wood stork foraging habitat conditions in the region of the traditional estuarine stork nesting colonies compared to 83 Base.
- When Shark Slough and Taylor Slough are considered together, Modified Water Deliveries is predicted to provide a 14% decline in habitat conditions compared to current conditions, and an 6% decline in habitat conditions compared to 83 Base.
- Using only Taylor Slough flows, Modified Water Deliveries is predicted to provide near NSM flows, and a slight improvement compared to 83 Base. In Taylor Slough, this would be viewed as favorable conditions. However, it should again be noted that the current distribution of flows is skewed to the east, closer to the C-111 drainage area than to Taylor Slough. It is probable that flows directed through Taylor Slough can potentially provide more and better wood stork habitat.

We have the following conclusions with respect to crocodiles:

- According to the Restudy's Crocodile Habitat Suitability measure, Modified Water Deliveries produces slightly less suitable crocodile and manatee habitat in northeastern

Florida Bay than under Test 7 Phase I and 1983 Base Condition, and much less than that predicted by NSM.

- According to predicted flow volumes into northeastern Florida Bay, Modified Water Deliveries might be expected to produce much less suitable crocodile and manatee habitat than predicted by Test 7 Phase I, about an equal amount compared to the 1983 Base Condition, slightly less than predicted by NSM. With respect to Test 7, these results appear somewhat inconsistent with the predicted salinity categories used to determine crocodile habitat suitability. The Restudy's crocodile habitat suitability measure is suspect in this evaluation probably due to its reliance on the gauge NP-33.
- Reduced flows into northeastern Florida Bay during the critical hatchling survival months (Aug - Dec) suggest that Modified Water Deliveries might be expected to produce much less suitable crocodile habitat than under Test 7 Phase I, equal to or slightly more than expected from the 83 Base, and equal to or less than that expected from NSM.
- It should be noted that under Modified Water Deliveries the distribution of flows is skewed to the east closer to the C-111 drainage area than Taylor Slough. Flows directed through Taylor Slough can potentially provide more and better crocodile habitat.
- According to the Restudy's Crocodile Habitat Suitability measure for North River Mouth, Modified Water Deliveries might be expected to produce slightly more suitable crocodile and manatee habitat in the western Everglades estuaries than under Test 7 Phase I, about the same amount of habitat as expected from the 1983 Base Condition, and less than NSM.
- According to predicted flow volumes into Shark Slough estuaries, Modified Water Deliveries might be expected to produce about the same amount of suitable crocodile and manatee habitat in the western Everglades estuaries as Test 7 Phase I, and less than both the 83 Base and NSM. The Crocodile Habitat Suitability measure for North River Mouth appears inconsistent with the results expected from predicted annual flow volumes into Shark Slough.
- Reduced flows into the Shark Slough estuaries during the critical hatchling survival months (Aug - Dec), that appear to peak earlier and at significantly lower volumes than NSM, suggest that Modified Water Deliveries, Test 7 Phase I, and the 83 Base might be expected to produce much less suitable crocodile habitat in the western Everglades estuaries than NSM, with Modified Water Deliveries and Test 7 Phase I producing the least.

We have the following conclusions with respect to snail kites:

- Overall, considering the two evaluation methods, it appears that in general Modified Water Deliveries is likely to have little or no significant effect on existing hydrologic conditions in the following areas used by nesting kites: Basin 14 - Southern WCA 3A and Southern 3A Snail Kite Habitat Basin.
- In Western 3A, an area also used by nesting kites, conditions under Modified Water Deliveries are predicted to be slightly worse than existing conditions.
- Compared to existing conditions, Modified Water Deliveries appears to provide no significant improvement in potential kite habitat from Eastern 3B southward to SW Shark Slough.
- According to these simulations, Modified Water Deliveries has little or no effect on existing hydrologic conditions in southern WCA-3A. This suggests that southern WCA-3A will continue to provide favorable snail kite habitat, distributed (in space and time) in a manner similar to today.
- This also implies that the long-term habitat changes that are expected to occur in parts of southern WCA-3A from water that is too deep and/or water that is ponded too long, will continue to occur under Modified Water Deliveries. In the long-term these conditions can result in changes in the biotic communities that can be detrimental to snail kite habitat in some parts of southern WCA-3A. Continuous flooding without periodic drying results in a loss of tree islands and other woody vegetation used by snail kites for nesting, perching, and roosting, as well as a loss of foraging habitat (Bennetts, pers. com.; Bennetts and Kitchens, 1997).
- A continuation of existing conditions also suggests that Modified Water Deliveries does little or nothing to improve (add to) the network of habitats available to snail kites. Bennetts and Kitchens [1997] believe that it is the extent of available habitat throughout a vast network that enables kites to persist. Bennetts and Kitchens [1997] hypothesize, and anecdotal evidence strongly supports, that a key to the long term survival of snail kites is to have some areas available when the inevitable and periodic fluctuations in the quality of other habitats occur. Bennetts and Kitchens [1997] describe the concept by the analogy of not having all of your eggs in one basket and that the baskets in which your eggs are in vary in quality over time.

Chapter 5

Conclusions

This report was undertaken to complete, in a very short timeframe, a comprehensive analysis of the effects of Experimental Water Deliveries and Modified Water Deliveries on Everglades National Park, with a focus on the potential effects on five endangered species. The scope of this topic necessarily means that the analysis was limited to a general overview, and the conclusions must therefore take the same tack.

Our analyses of the Experimental Water Deliveries Program show that the results are mixed. Hydrologically, there have been benefits in the timing of the S12 flows, improved L-31W/Taylor Slough hydroperiods, and hydroperiod increases in Northeast Shark Slough. On the other hand, flows into the Park and, in particular, into the Shark Slough estuaries are reduced, and water levels and hydroperiods along the Park's eastern boundary are lower. Most importantly, Experimental Water Deliveries has not fundamentally addressed the problem of distribution of flow during wet years. During above average rainfall and flow conditions, constraints on S-333 use preclude a more natural distrubution of flow between eastern and western Shark Slough.

With respect to the effects on five endangered species, we find that Experimental Water Deliveries did not appreciably affect the western subpopulation of the Cape Sable seaside sparrow relative to Minimum Deliveries. Some of the eastern subpopulations potentially have been adversely affected. Wood storks, crocodiles, and manatees have been adversely affected by reduced flow to Shark Slough estuaries, as well has unnaturally high flows into the lower C-111 and the Park's Eastern Panhandle. Conditions for the snail kite have not changed substantially in Experimental Water Deliveries. However, the perpetutation of the current conditions is not generally seen as favorable to the snail kite.

We also investigated three alternatives for Experimental Water Deliveries. We felt constrained on the scope of what could be reasonably included under EWD. The intent was to investigate directions for further detailed analyses rather than the development of comphrensive alternatives. We fully recognized and expect that the alternatives can and should be improved to maximize over-all ecosystem and societal benefits.

Our investigations indicate that plans which provide the best overall ecological benefit also provided the most benefit for the Cape Sable seaside sparrow. Operational plans that attempt to reproduce pre-drainage flow distributions (to the extent possible) result in benefits to the wood stork, manatee and crocodile as well as the sparrow. However, the plans investigated resulted in adverse impacts to the snail kite. It is almost certain that an alternative that retains the overall benefits while reducing effects on the kite can be developed.

Our investigations of the Modified Water Deliveries Project lead us to conclude that the potential consequences are mixed. Modified Water Deliveries does result in benefits to the Cape Sable seaside sparrow. However, this is at the expense of WCA-3B and the Shark Slough estuaries. Flow which would have been routed over the sparrow's western habitat are diverted into WCA-3B. If Tamiami Trail remains a constraint, then these flows remain in WCA-3B, where they likely result in tree island damage.

The Tamiami Trail and its hydrologic consequences are the single most important factor in determing the effects of Modified Water Deliveries. If Tamiami Trail remains as it is today, as a constraint to flow into Northeast Shark Slough, it is unlikely that the authorized Modified Water Deliveries can be operated to result in substantial ecological benefit. If Tamiami Trail can be removed as a hydrologic constraint, then it is likely that the benefits predicted in the GDM can be attained. Furthermore, given the performance of the WCA-3B and the flood control components in Northeast Shark Slough, a re-evaluation of the Modified Water Deliveries Project can likely result in signficantly increased benefits.

Appendix A

Snail Kite Graphics

For completeness, we have included all of the graphics used to generate the tables analyzed in the sections on the snail kite.

A.1 Experimental Water Deliveries

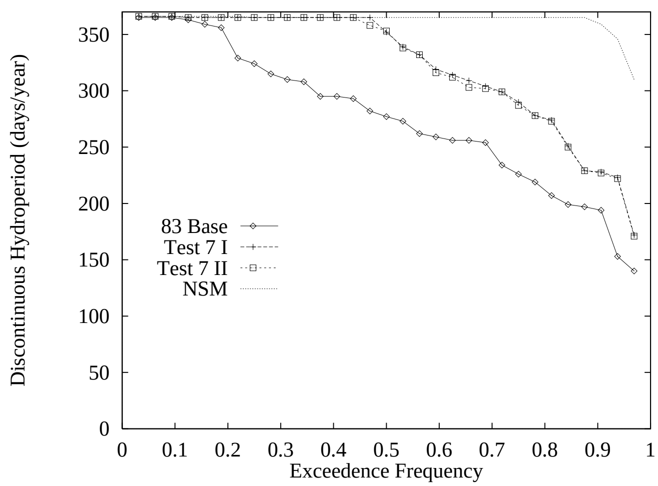


Figure 142: Hydroperiod frequencies for NE Shark River Slough (Indicator Region 11).

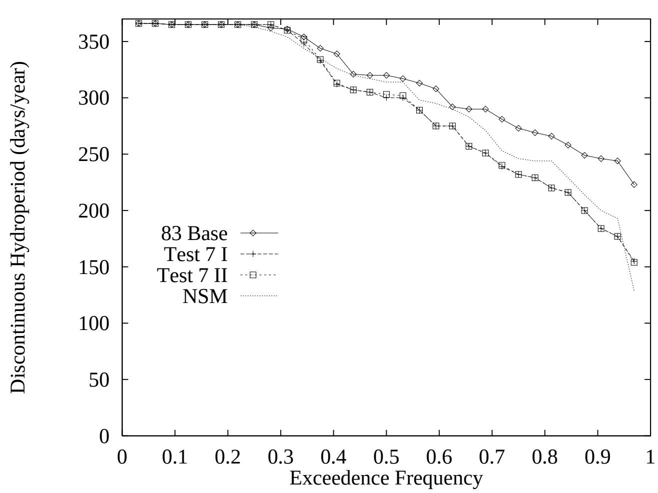


Figure 143: Hydroperiod frequencies for NW Shark River Slough (Indicator Region 12).

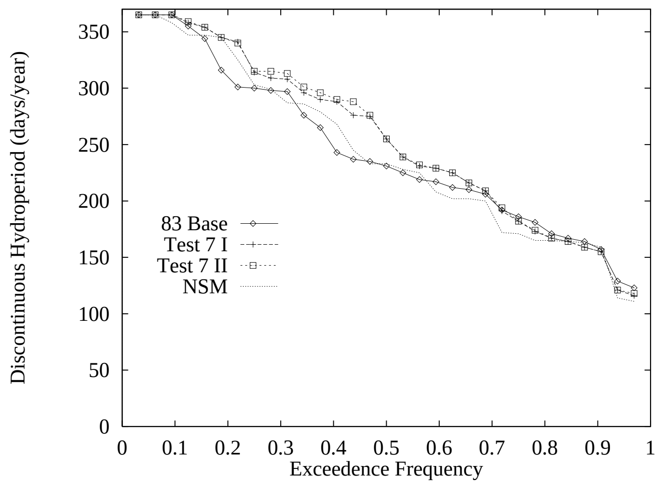


Figure 144: Hydroperiod frequencies for East Slough (Indicator Region 13).

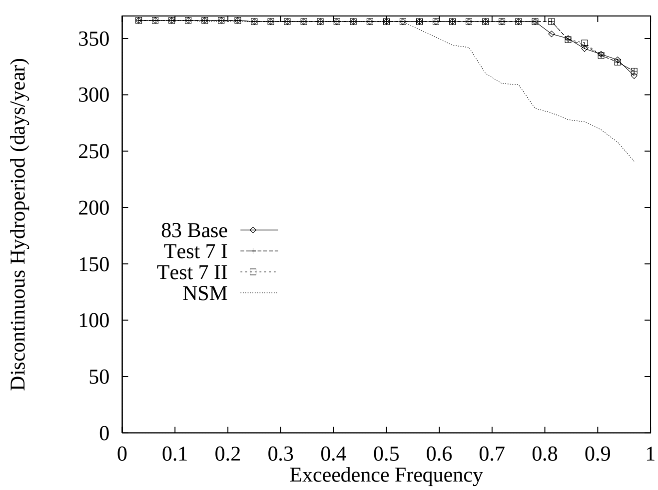


Figure 145: Hydroperiod frequencies for Southern Water Conservation Area 3A (Indicator Region 14.)

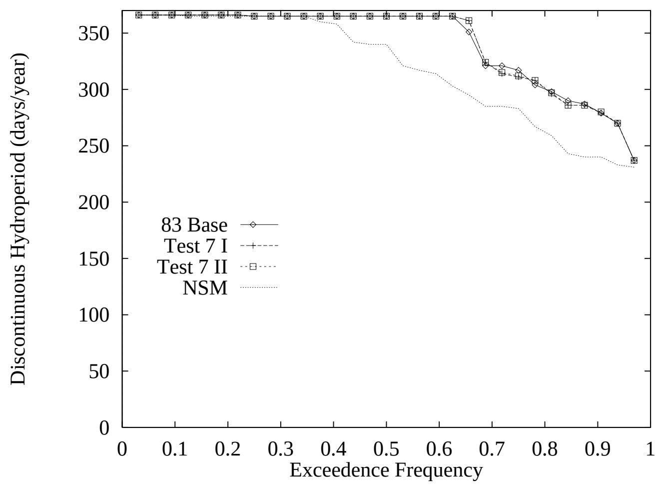


Figure 146: Hydroperiod frequencies for South Central Water Conservation Area 3A (Indicator Region 17.)

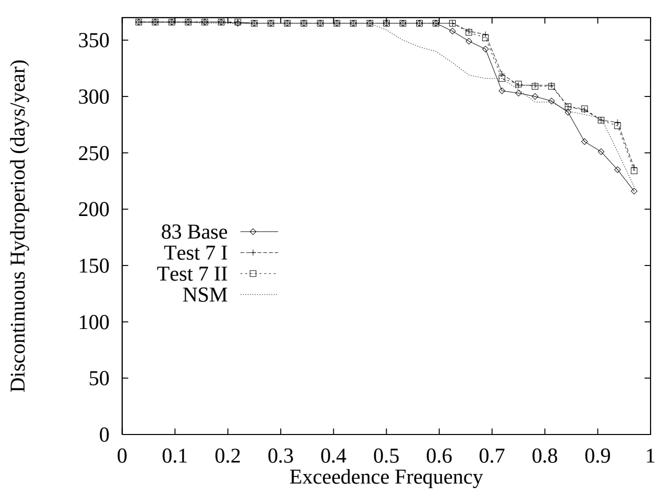


Figure 147: Hydroperiod frequencies for West Water Conservation Area 3B (Indicator Region 15.)

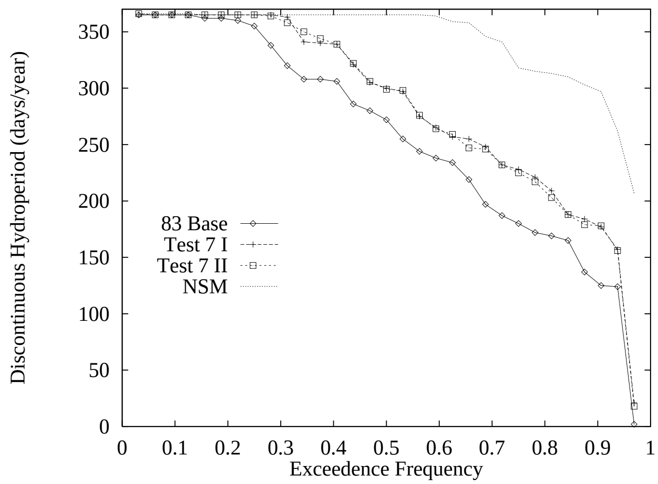


Figure 148: Hydroperiod frequencies for East Water Conservation Area 3B (Indicator Region 16.)

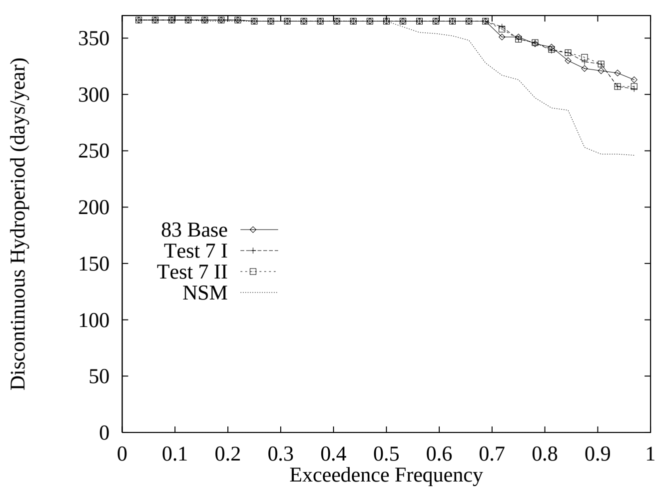


Figure 149: Hydroperiod frequencies for Southern WCA-3A snail kite habitat.

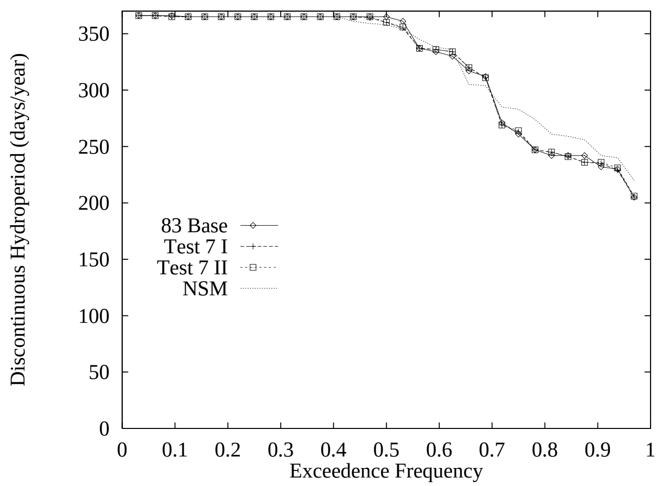


Figure 150: Hydroperiod frequencies for Western WCA-3A snail kite habitat.

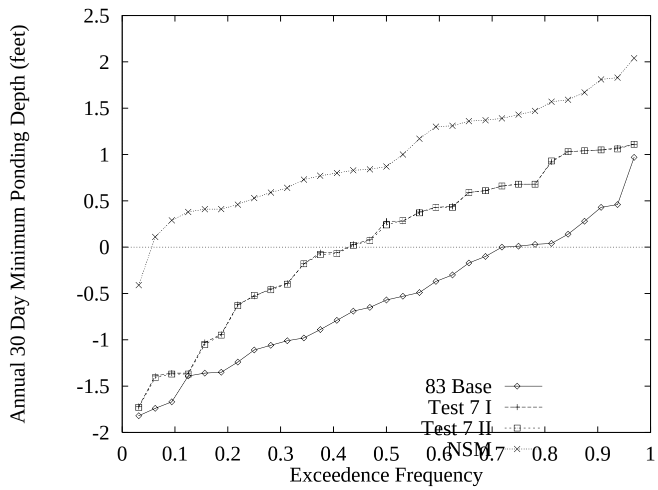


Figure 151: Annual stage exceedence frequency for the 30 Day continuous minimum for North East Shark Slough (Indicator Region 11).

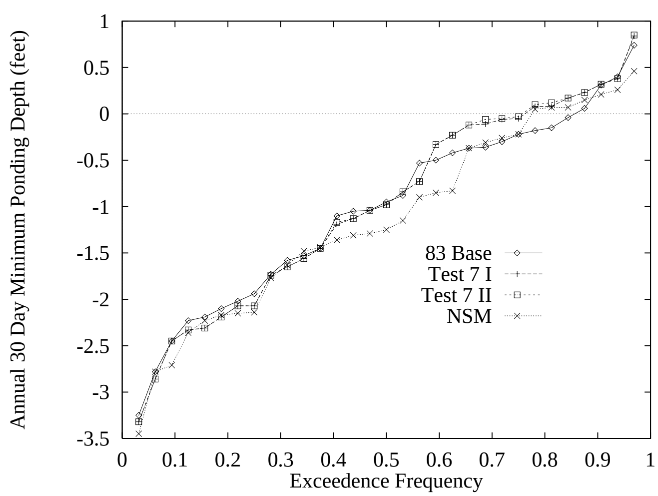


Figure 152: Annual stage exceedence frequency for the 30 Day continuous minimum for East Slough (Indicator Region 13).

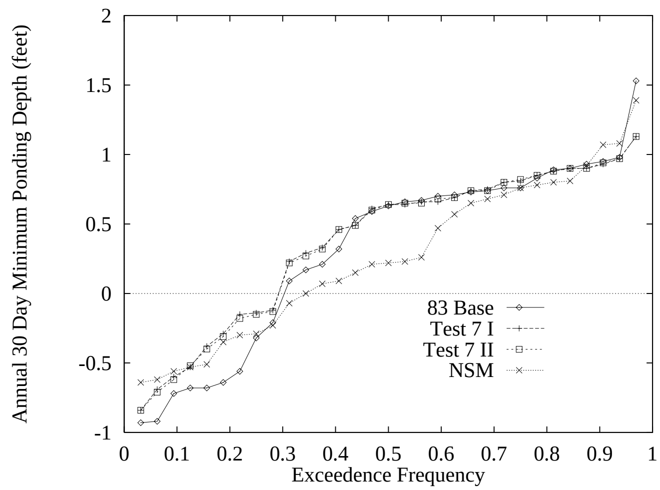


Figure 153: Annual stage exceedence frequency for the 30 Day continuous minimum for West WCA-3B (Indicator Region 15).

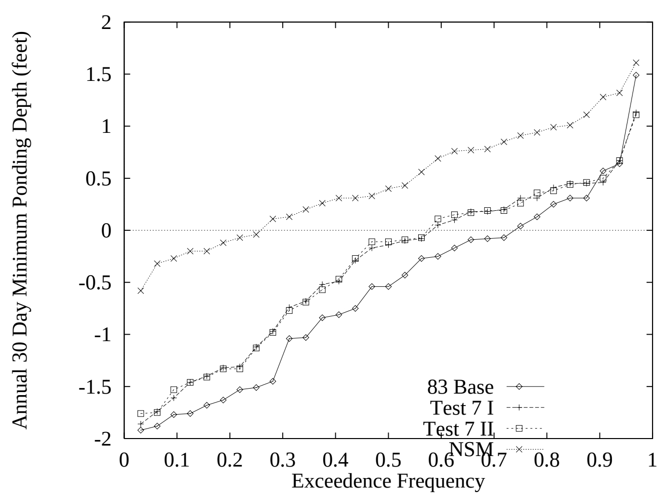


Figure 154: Annual stage exceedence frequency for the 30 Day continuous minimum for West WCA-3B (Indicator Region 16).

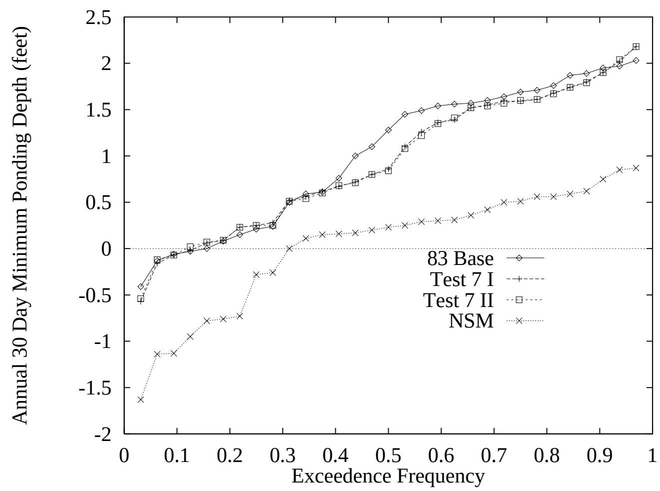


Figure 155: Annual stage exceedence frequency for the 30 Day continuous minimum for Southern WCA-3A Snail Kite Habitat).

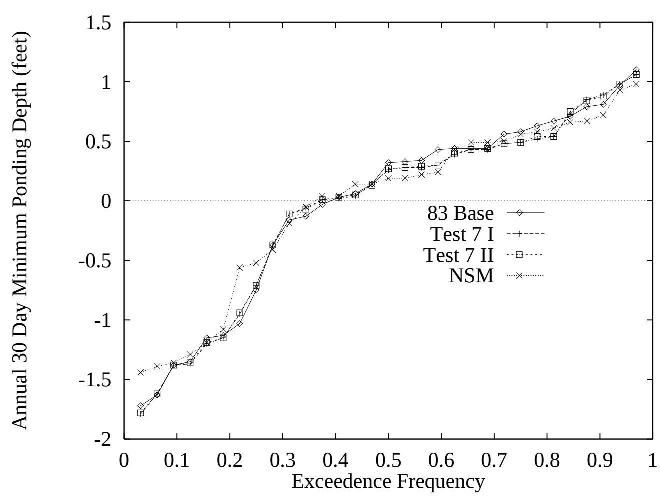


Figure 156: Annual stage exceedence frequency for the 30 Day continuous minimum for Western WCA-3A Snail Kite Habitat.

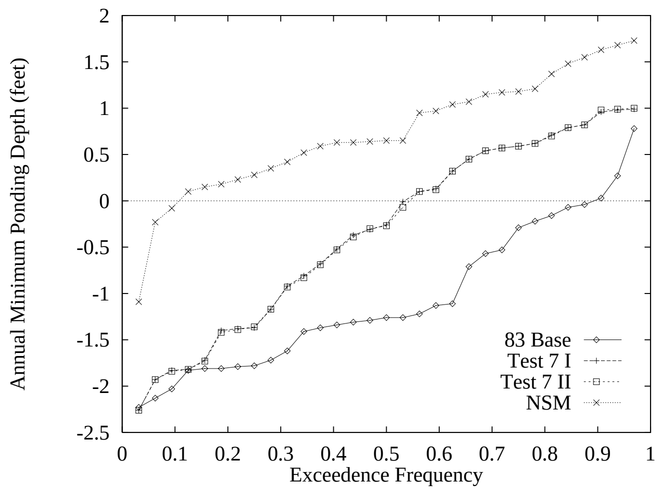


Figure 157: Annual stage exceedence frequency for the minimum for North East Shark Slough (Indicator Region 11).

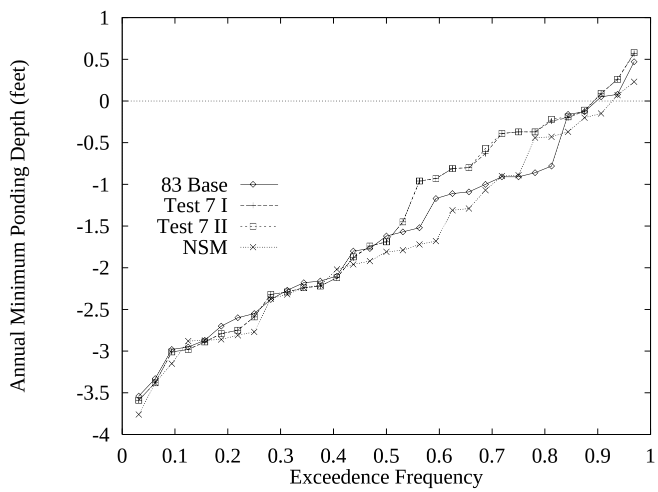


Figure 158: Annual stage exceedence frequency for the minimum for East Slough (Indicator Region 13).

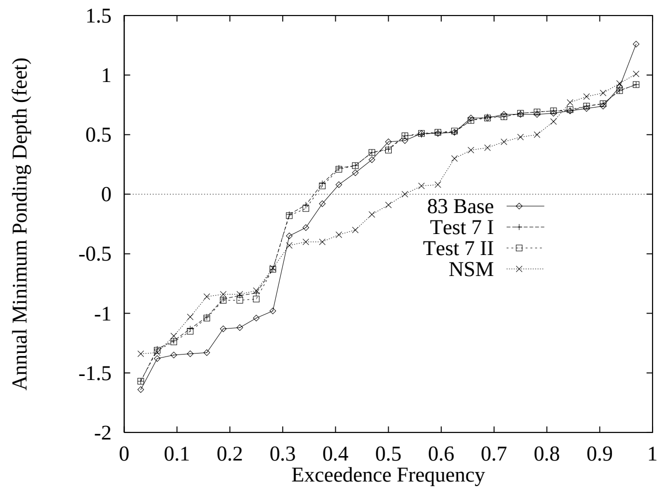


Figure 159: Annual stage exceedence frequency for the minimum for West WCA-3B (Indicator Region 15).

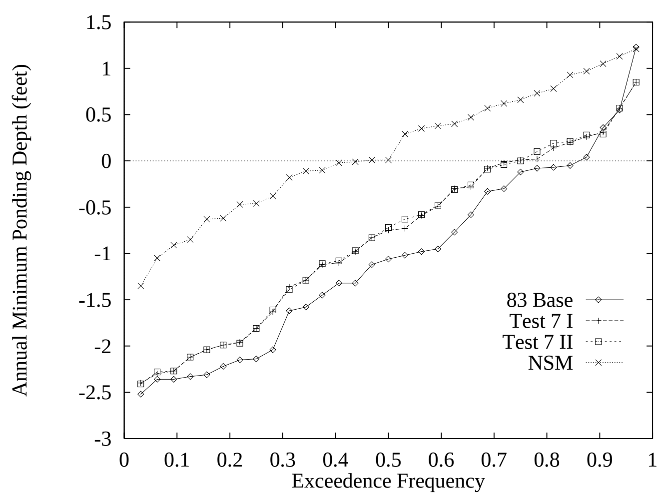


Figure 160: Annual stage exceedence frequency for the minimum for East WCA-3B (Indicator Region 16).

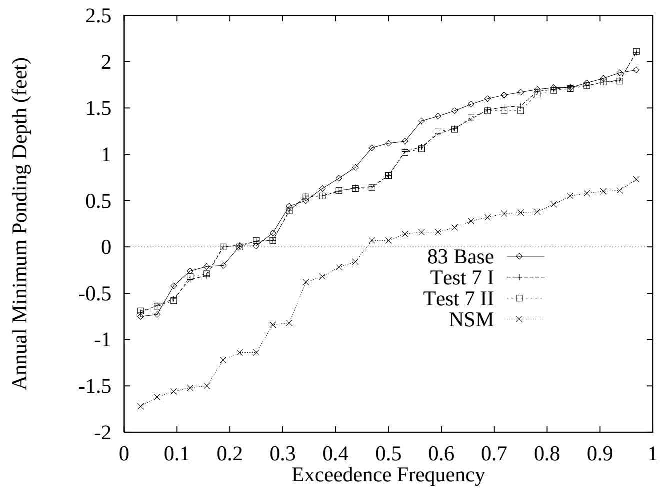


Figure 161: Annual stage exceedence frequency for the minimum for Southern WCA 3A (Indicator Region 14).

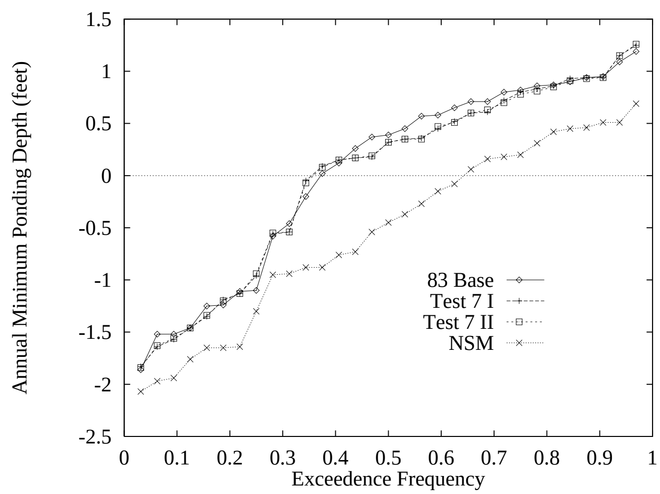


Figure 162: Annual stage exceedence frequency for the minimum for South Central WCA 3A (Indicator Region 17).

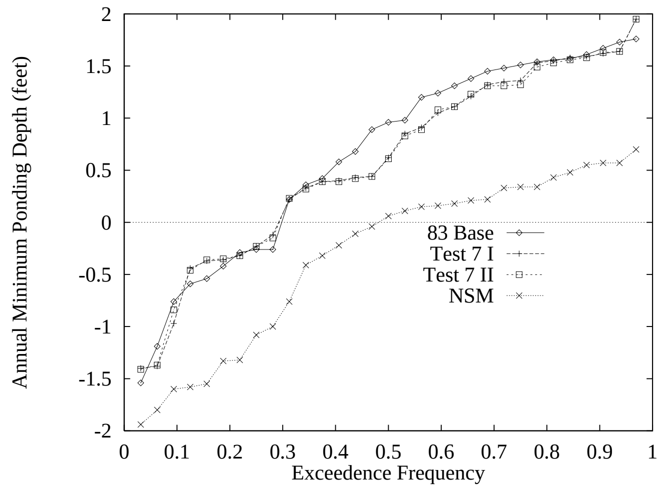


Figure 163: Annual stage exceedence frequency for the minimum for Southern WCA-3A Snail Kite Habitat.

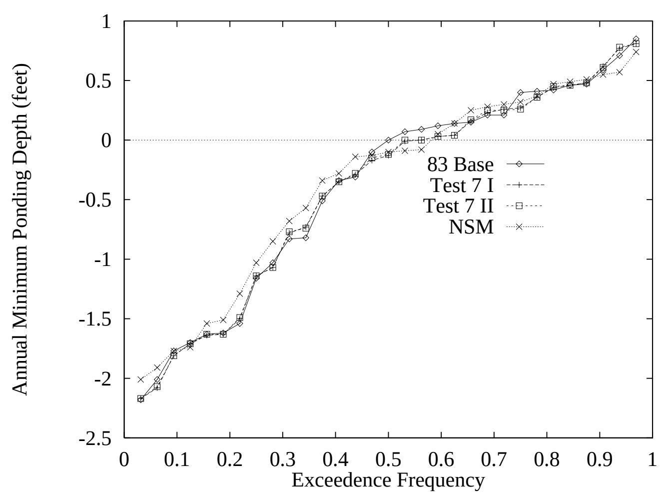


Figure 164: Annual stage exceedence frequency for the minimum for Western WCA-3A Snail Kite Habitat.

A.2 Alternatives

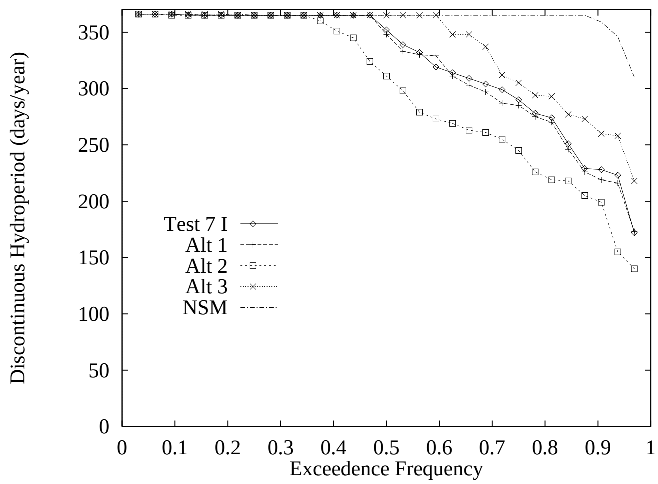


Figure 165: Hydroperiod frequencies for NE Shark River Slough (Indicator Region 11).

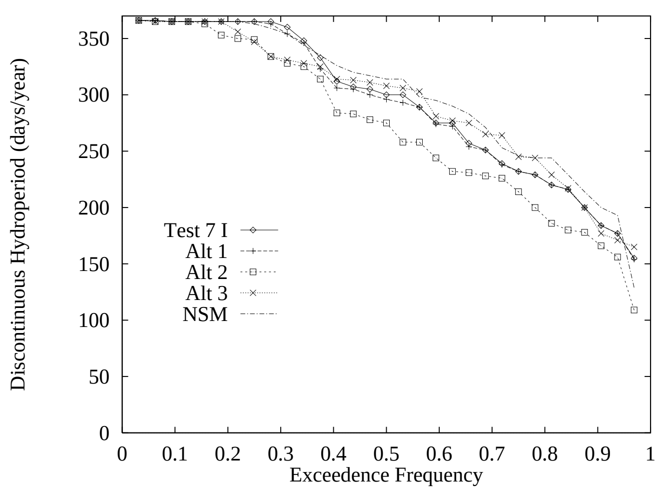


Figure 166: Hydroperiod frequencies for NW Shark River Slough (Indicator Region 12).

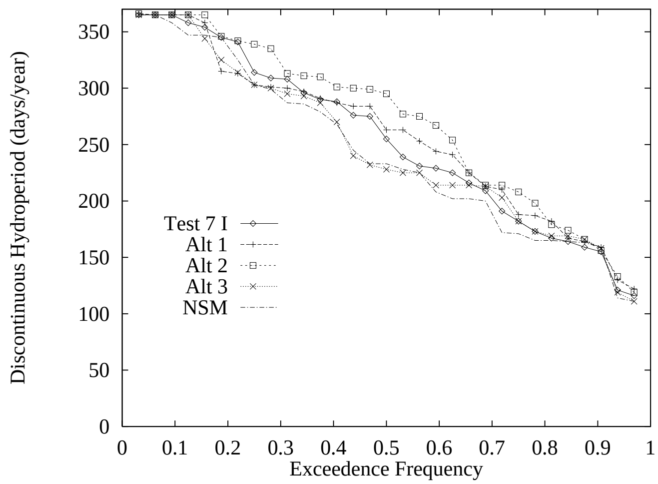


Figure 167: Hydroperiod frequencies for East Slough (Indicator Region 13).

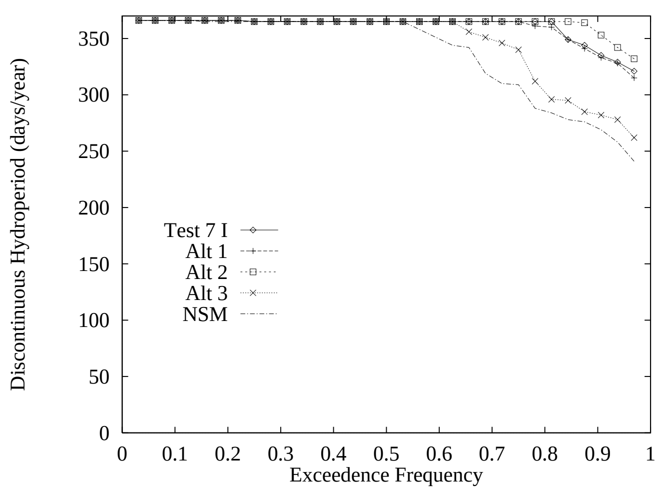


Figure 168: Hydroperiod frequencies for Southern Water Conservation Area 3A (Indicator Region 14.)

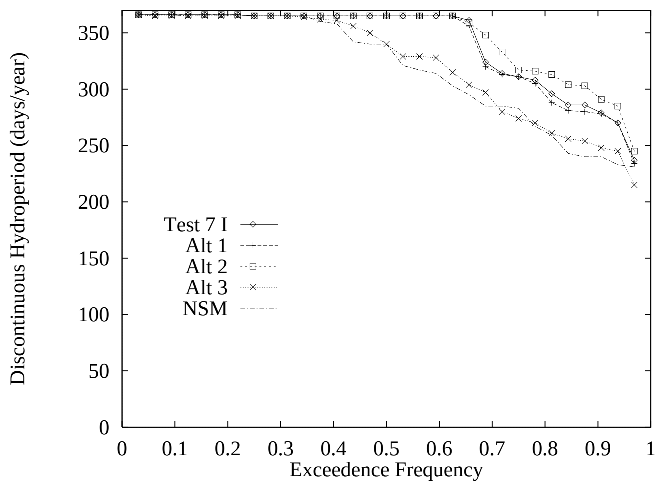


Figure 169: Hydroperiod frequencies for South Central Water Conservation Area 3A (Indicator Region 17.)

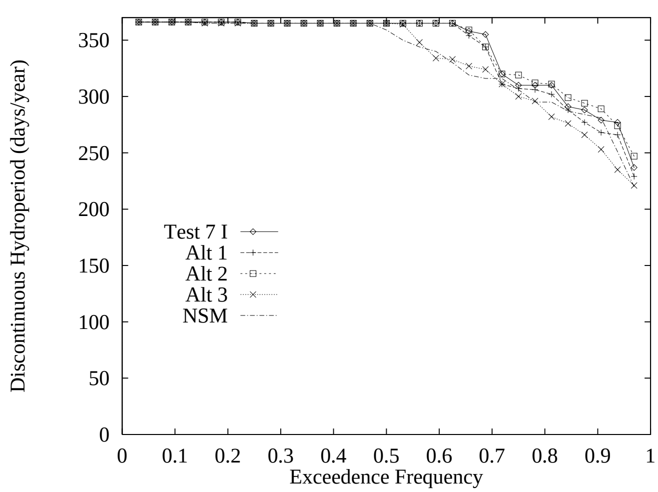


Figure 170: Hydroperiod frequencies for West Water Conservation Area 3B (Indicator Region 15.)

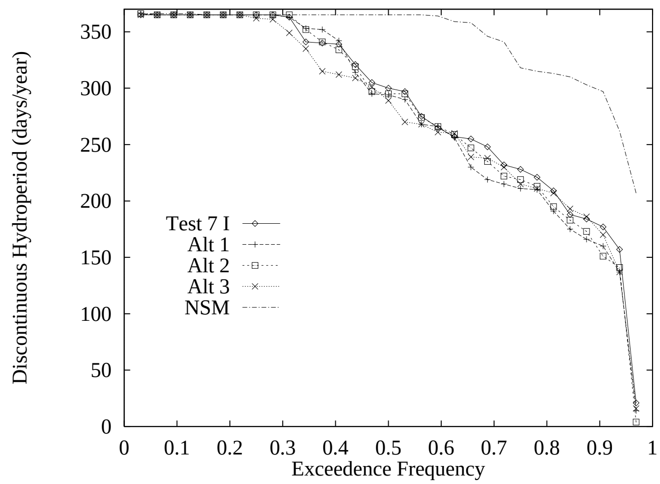


Figure 171: Hydroperiod frequencies for East Water Conservation Area 3B (Indicator Region 16.)

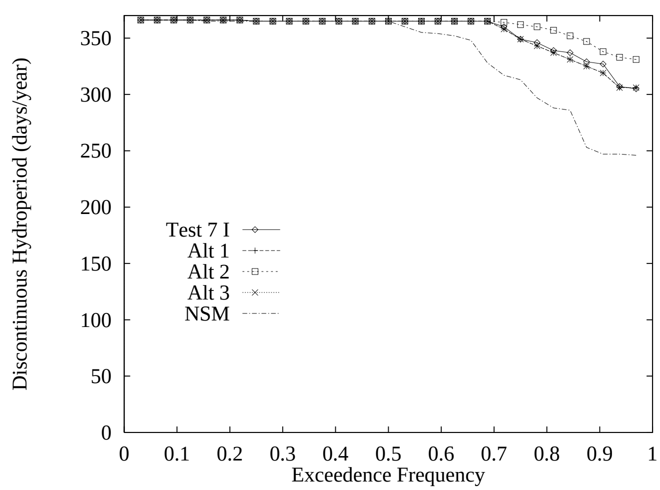


Figure 172: Hydroperiod frequencies for Southern WCA-3A snail kite habitat.

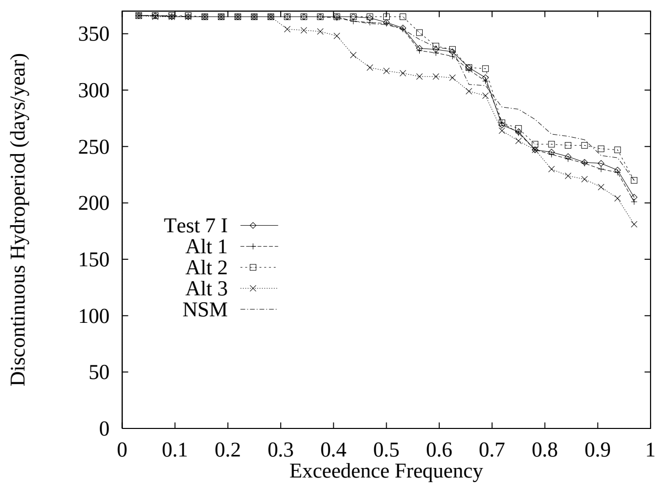


Figure 173: Hydroperiod frequencies for Western WCA-3A snail kite habitat.

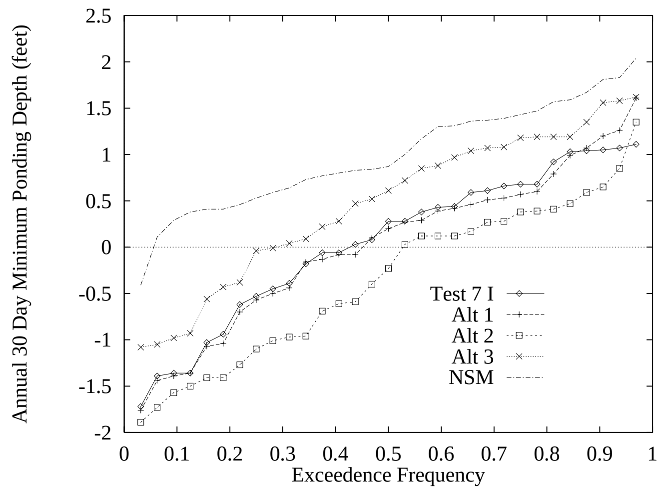


Figure 174: Annual stage exceedence frequency for the 30 Day continuous minimum for North East Shark Slough (Indicator Region 11).

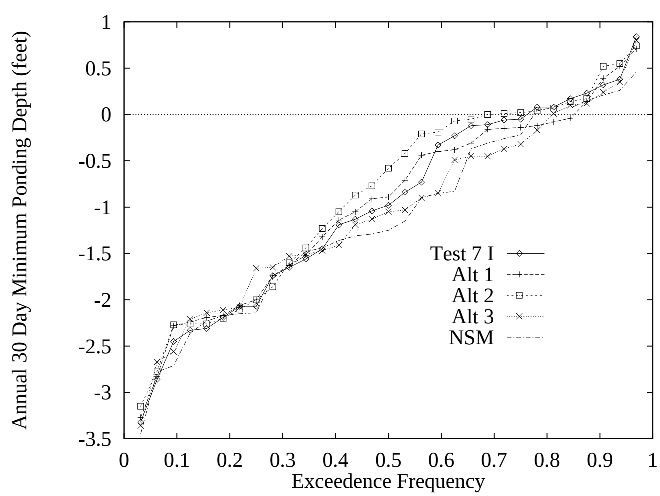


Figure 175: Annual stage exceedence frequency for the 30 Day continuous minimum for East Slough (Indicator Region 13).

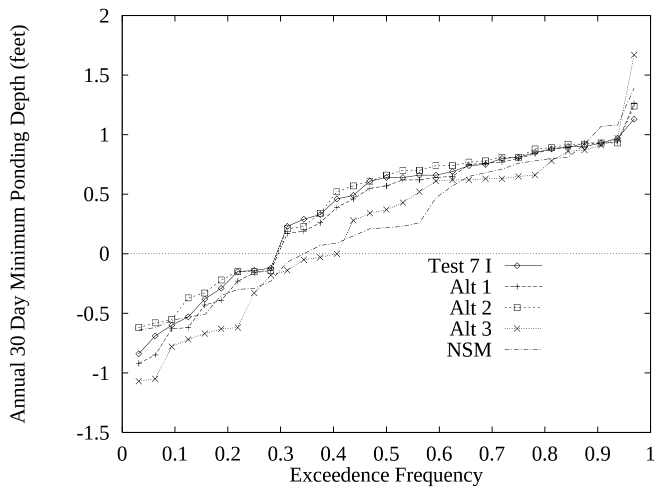


Figure 176: Annual stage exceedence frequency for the 30 Day continuous minimum for West WCA-3B (Indicator Region 15).

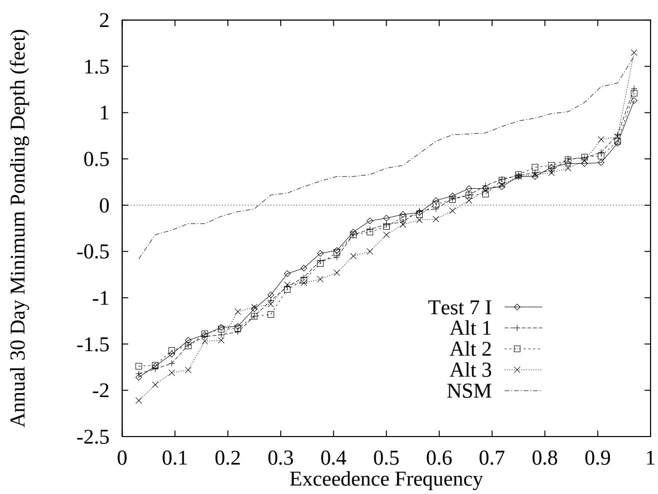


Figure 177: Annual stage exceedence frequency for the 30 Day continuous minimum for West WCA-3B (Indicator Region 16).

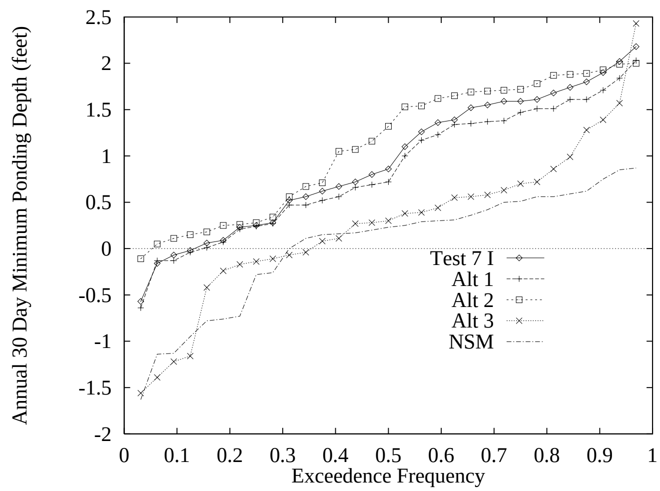


Figure 178: Annual stage exceedence frequency for the 30 Day continuous minimum for Southern WCA-3A Snail Kite Habitat).

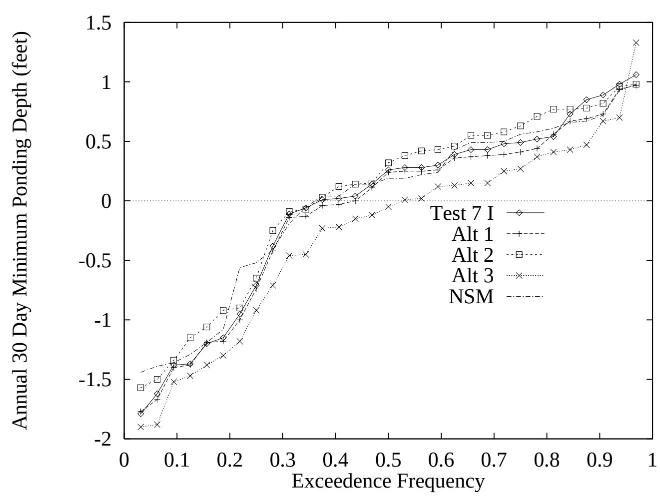


Figure 179: Annual stage exceedence frequency for the 30 Day continuous minimum for Western WCA-3A Snail Kite Habitat.

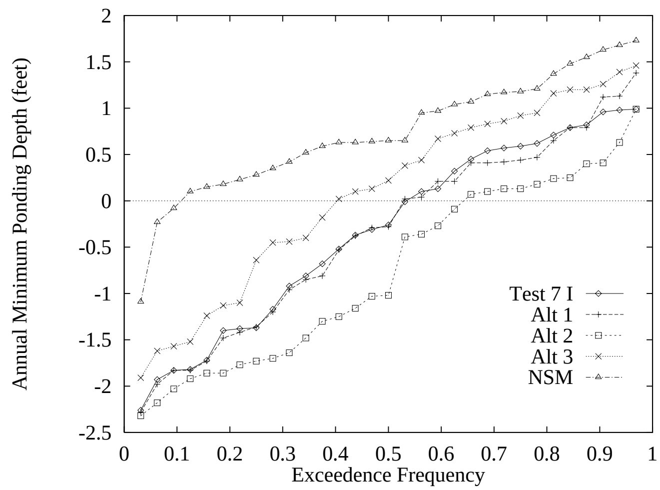


Figure 180: Annual stage exceedence frequency for the minimum for North East Shark Slough (Indicator Region 11).

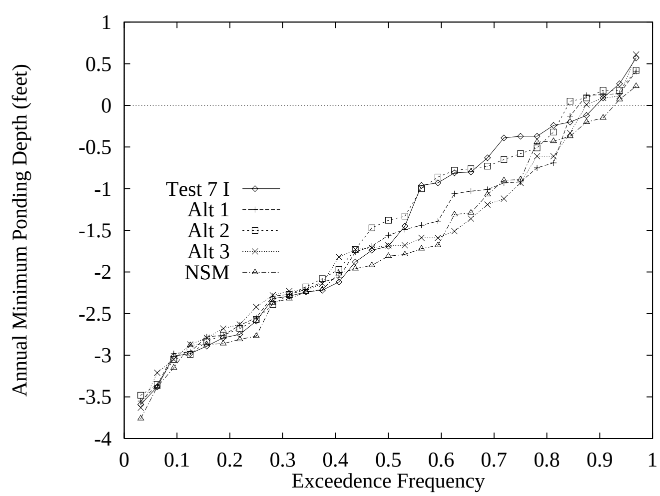


Figure 181: Annual stage exceedence frequency for the minimum for East Slough (Indicator Region 13).

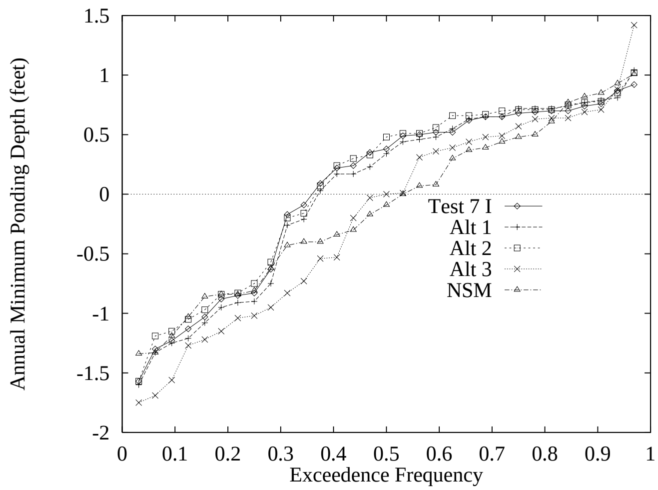


Figure 182: Annual stage exceedence frequency for the minimum for West WCA-3B (Indicator Region 15).

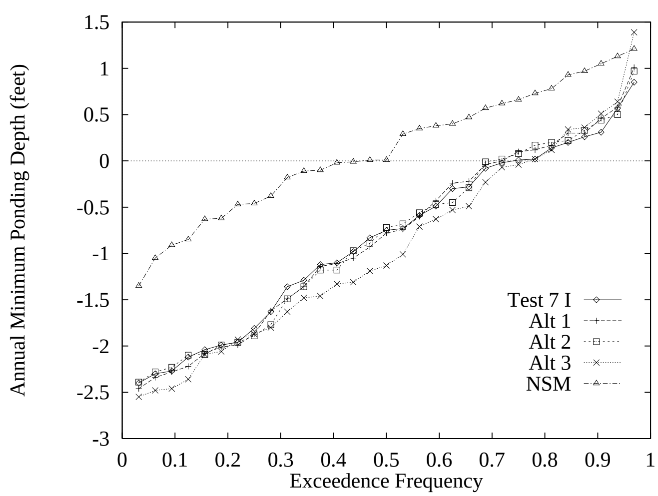


Figure 183: Annual stage exceedence frequency for the minimum for East WCA-3B (Indicator Region 16).

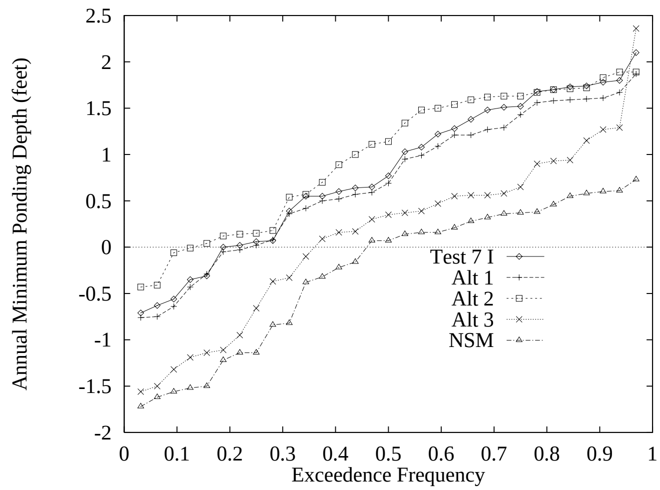


Figure 184: Annual stage exceedence frequency for the minimum for Southern WCA 3A (Indicator Region 14).

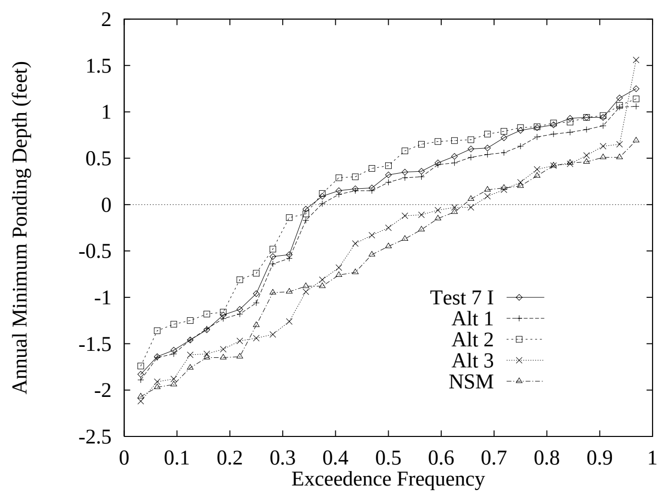


Figure 185: Annual stage exceedence frequency for the minimum for South Central WCA 3A (Indicator Region 17).

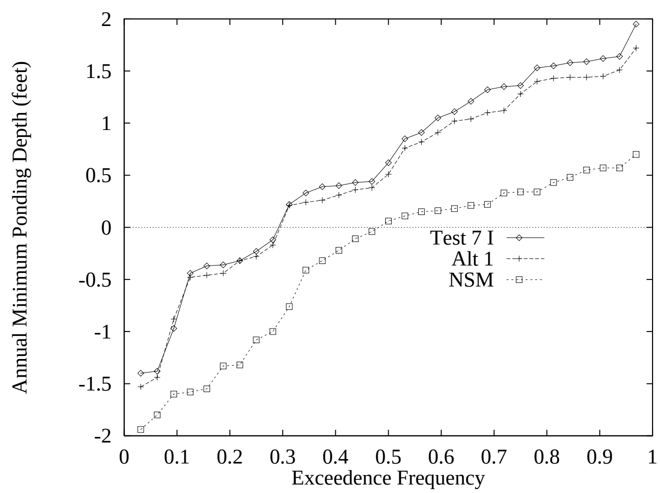


Figure 186: Annual stage exceedence frequency for the minimum for Southern WCA-3A Snail Kite Habitat.

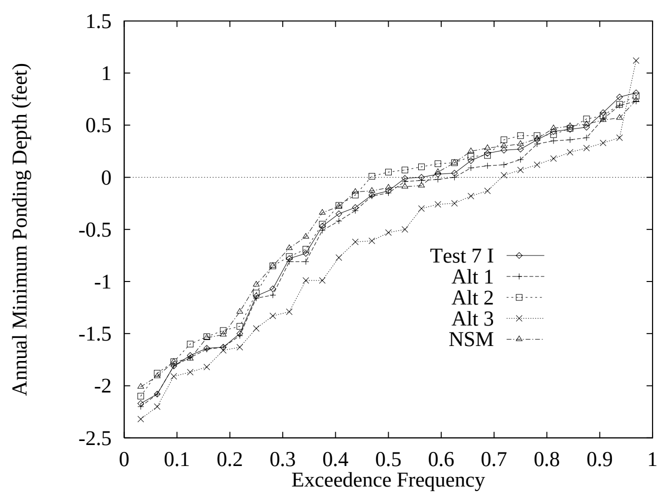


Figure 187: Annual stage exceedence frequency for the minimum for Western WCA-3A Snail Kite Habitat.

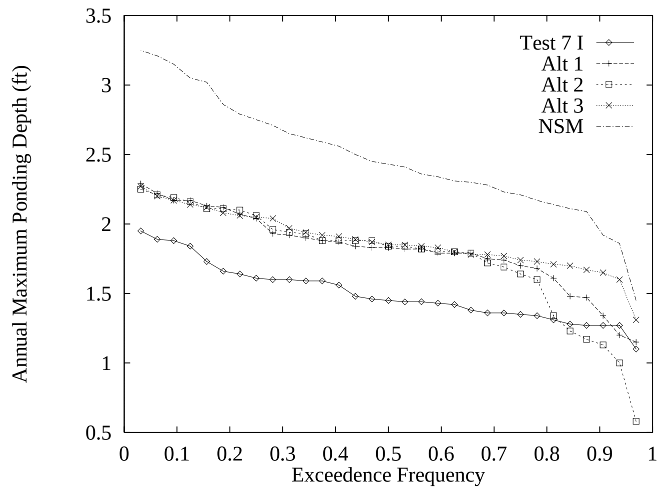


Figure 188: Annual maximum stage exceedence frequency for North East Shark Slough (Indicator Region 11).

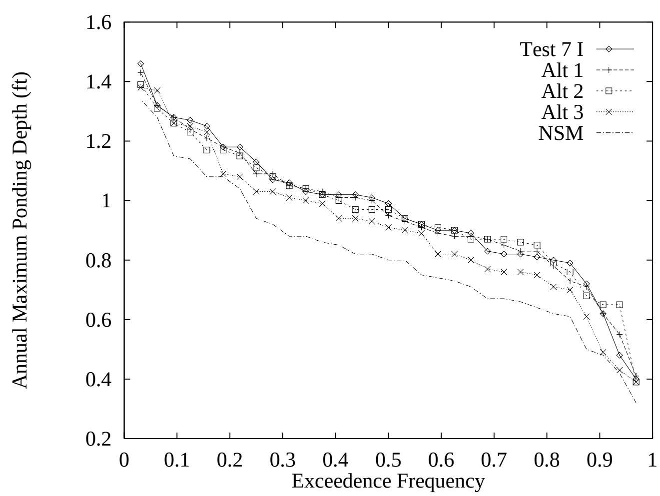


Figure 189: Annual maximum stage exceedence frequency for East Slough (Indicator Region 13).

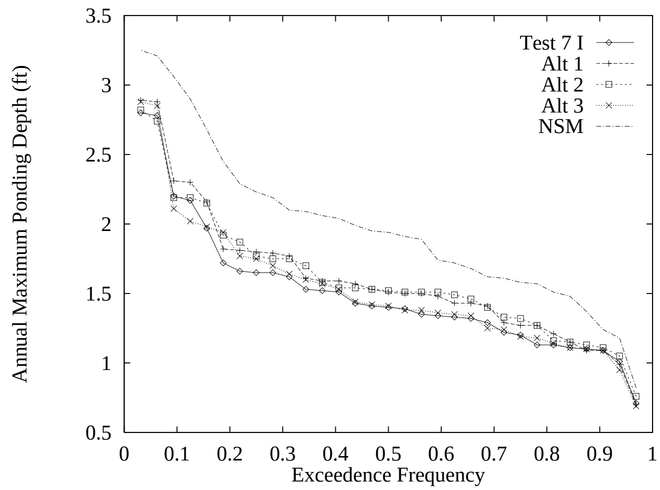


Figure 190: Annual maximum stage exceedence frequency for West WCA-3B (Indicator Region 15).

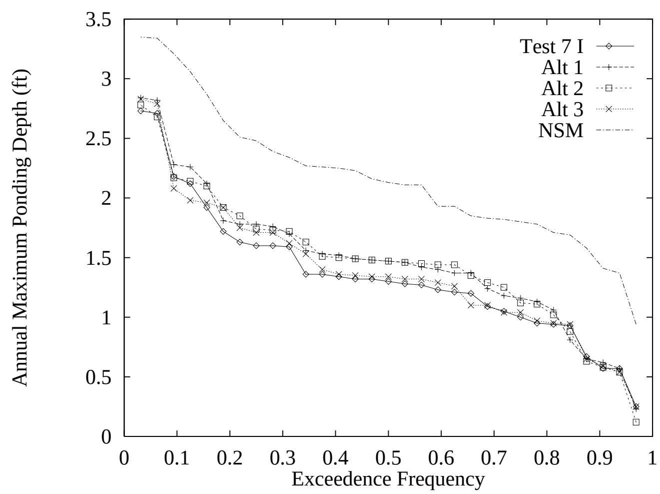


Figure 191: Annual maximum stage exceedence frequency for East WCA-3B (Indicator Region 16).

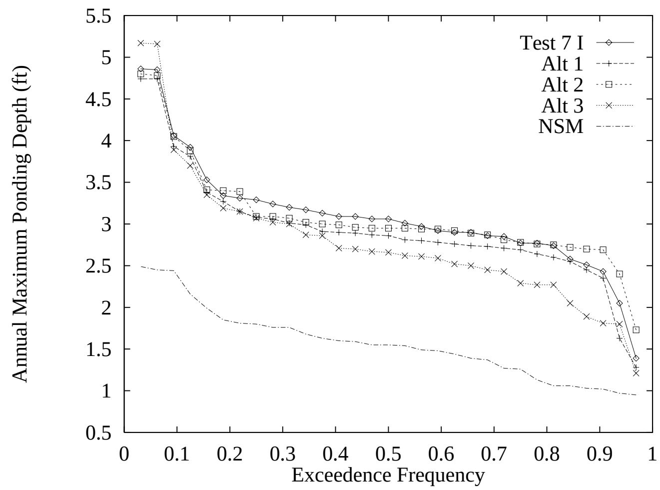


Figure 192: Annual maximum stage exceedence frequency for Southern WCA 3A (Indicator Region 14).

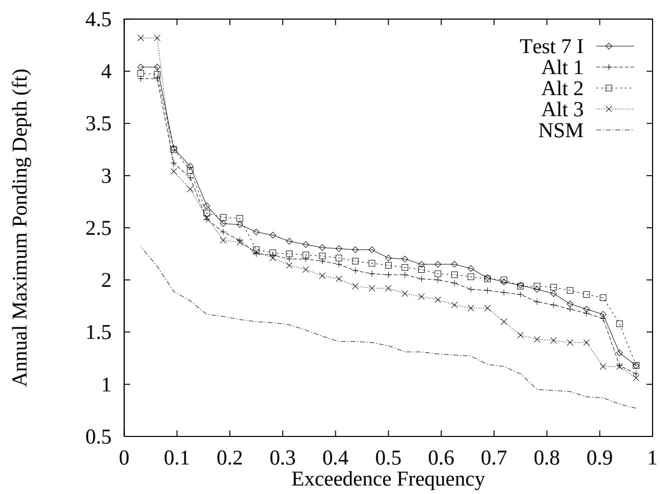


Figure 193: Annual maximum stage exceedence frequency for South Central WCA 3A (Indicator Region 17).

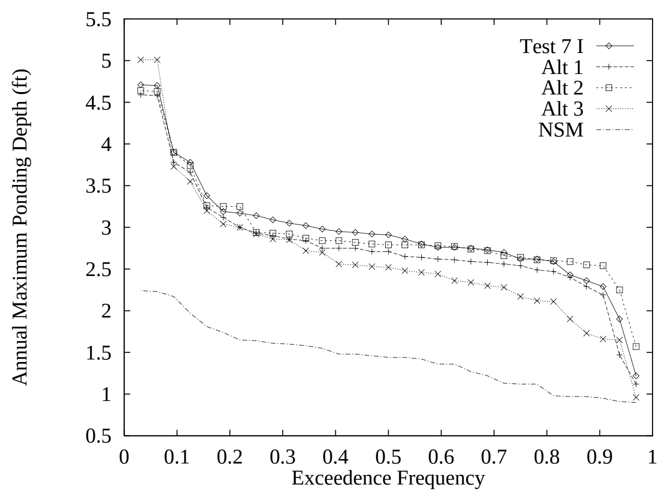


Figure 194: Annual maximum stage exceedence frequency for Southern WCA-3A Snail Kite Habitat.

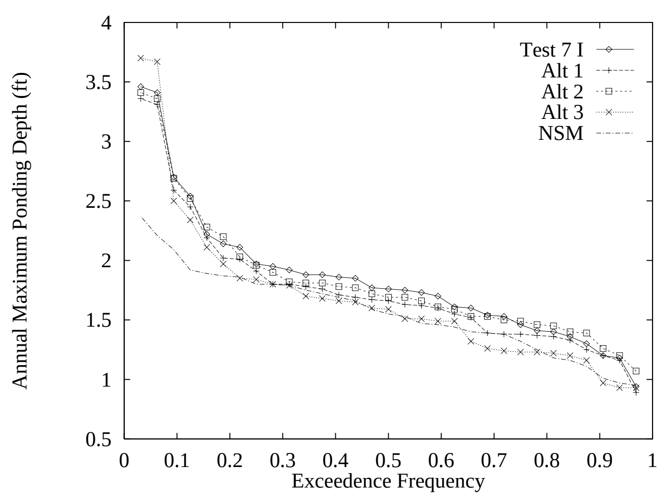


Figure 195: Annual maximum stage exceedence frequency for Western WCA-3A Snail Kite Habitat.

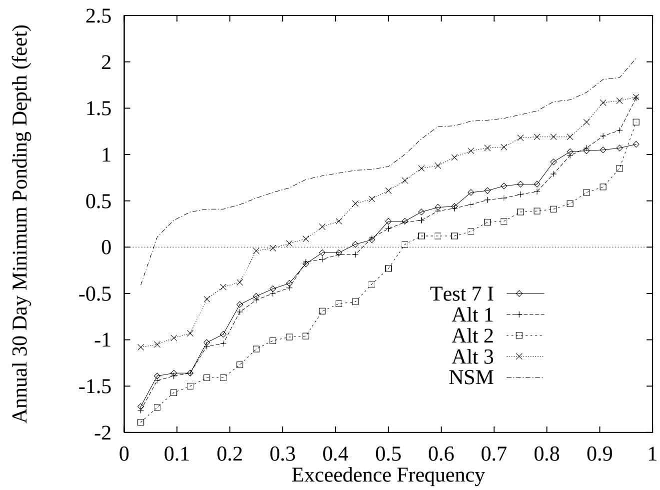


Figure 196: Annual exceedence frequency for the 30-day average maximum ponded depth for North East Shark Slough (Indicator Region 11).

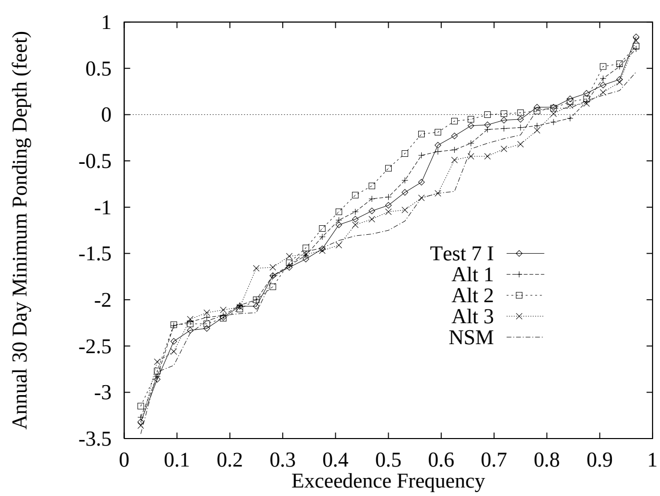


Figure 197: Annual exceedence frequency for the 30-day average maximum ponded depth for East Slough (Indicator Region 13).

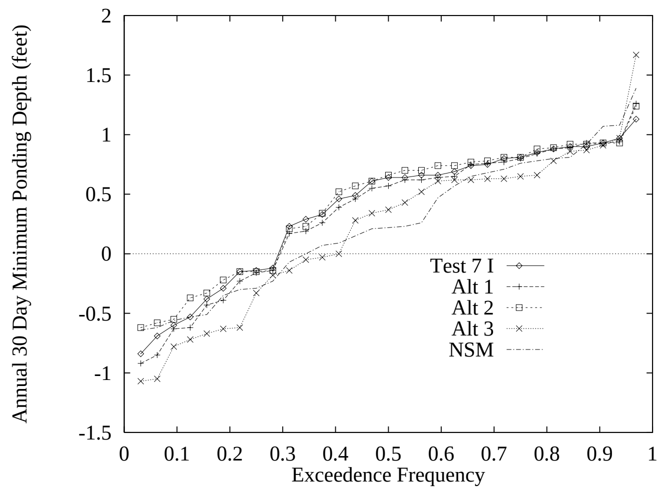


Figure 198: Annual exceedence frequency for the 30-day average maximum ponded depth for West WCA-3B (Indicator Region 15).

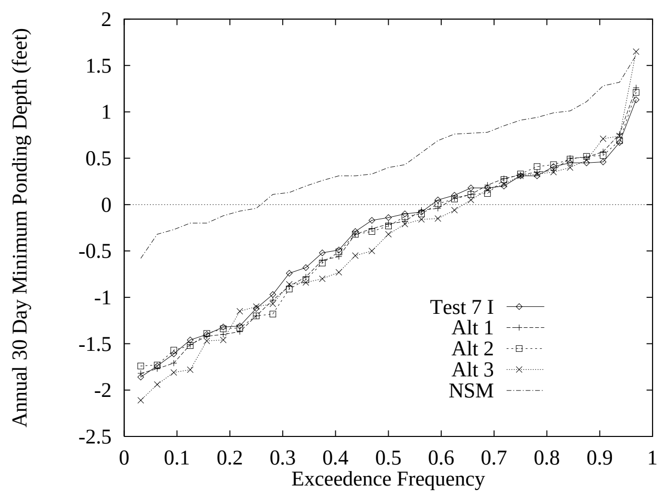


Figure 199: Annual exceedence frequency for the 30-day average maximum ponded depth for East WCA-3B (Indicator Region 16).

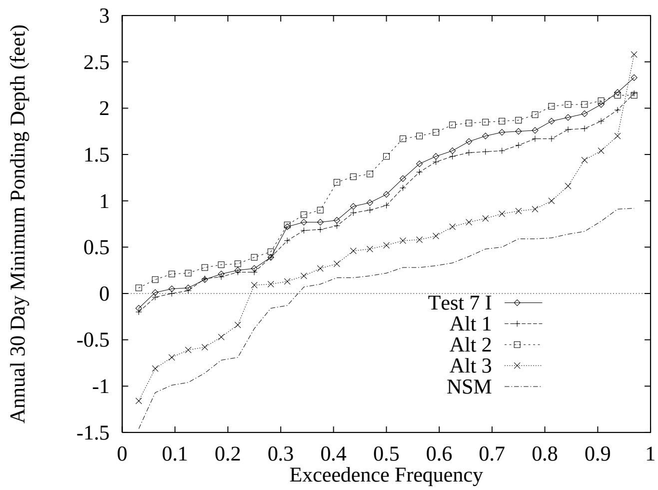


Figure 200: Annual exceedence frequency for the 30-day average maximum ponded depth for Southern WCA 3A (Indicator Region 14).

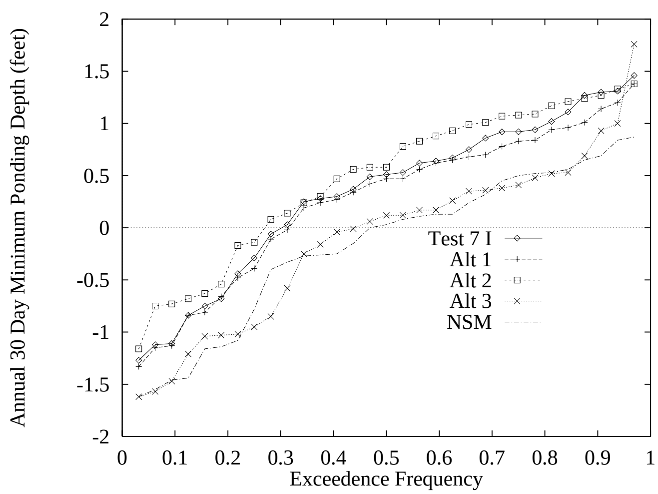


Figure 201: Annual exceedence frequency for the 30-day average maximum ponded depth for South Central WCA 3A (Indicator Region 17).

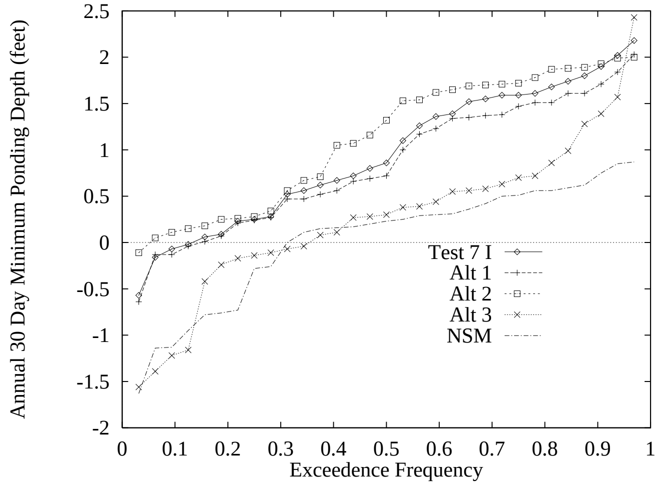


Figure 202: Annual exceedence frequency for the 30-day average maximum ponded depth for Southern WCA-3A Snail Kite Habitat.

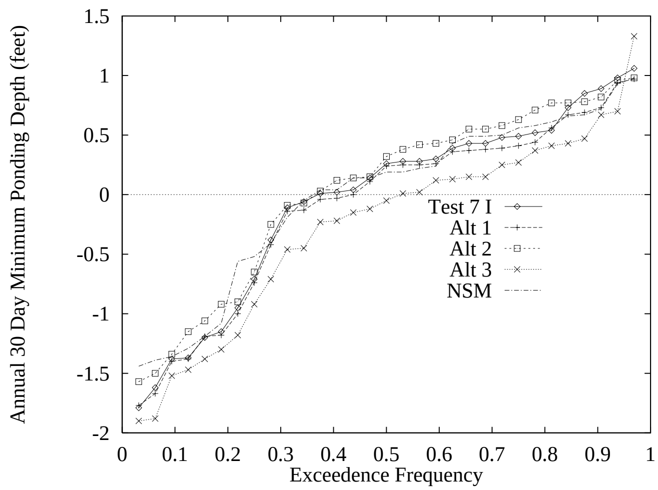


Figure 203: Annual exceedence frequency for the 30-day average maximum ponded depth for Western WCA-3A Snail Kite Habitat.

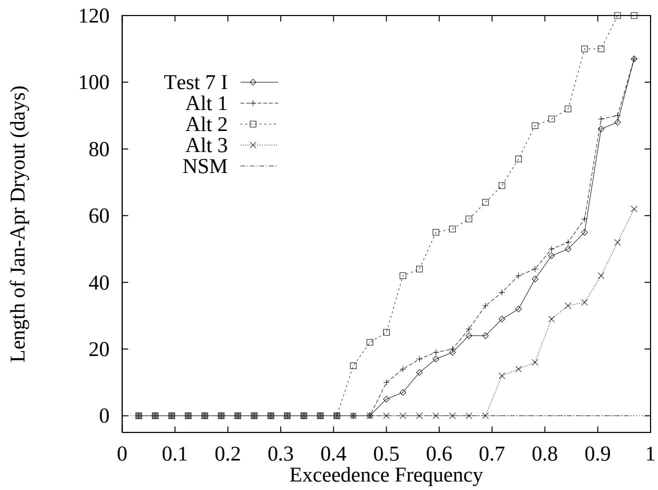


Figure 204: Annual exceedence frequency for the maximum number of days of continuous dryout between January 1 and April 30 for North East Shark Slough (Indicator Region 11).

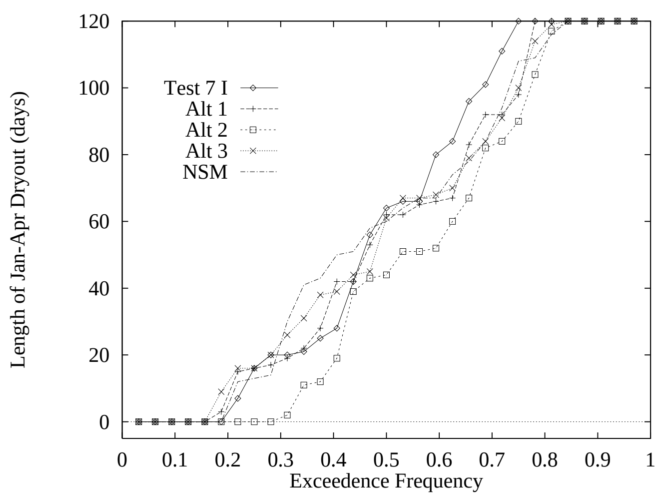


Figure 205: Annual exceedence frequency for the maximum number of days of continuous dryout between January 1 and April 30 for East Slough (Indicator Region 13).

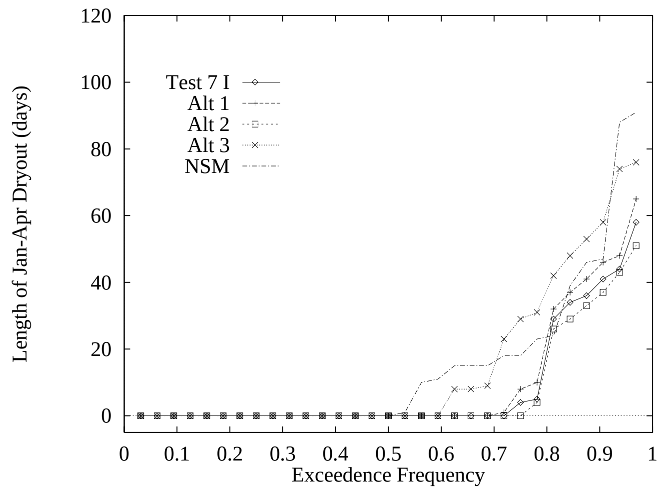


Figure 206: Annual exceedence frequency for the maximum number of days of continuous dryout between January 1 and April 30 for West WCA-3B (Indicator Region 15).

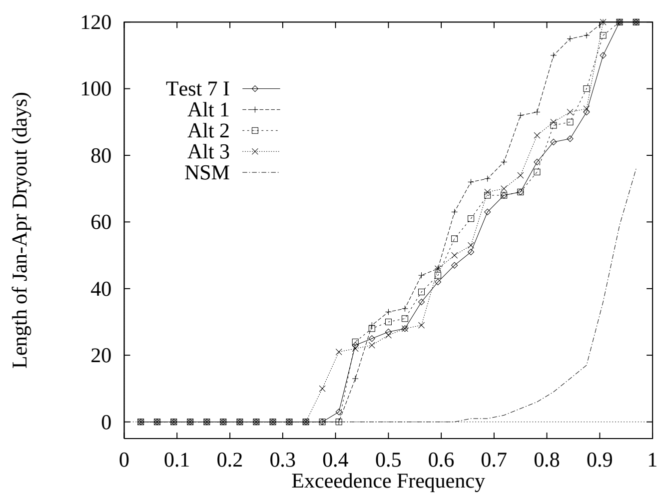


Figure 207: Annual exceedence frequency for the maximum number of days of continuous dryout between January 1 and April 30 for East WCA-3B (Indicator Region 16).

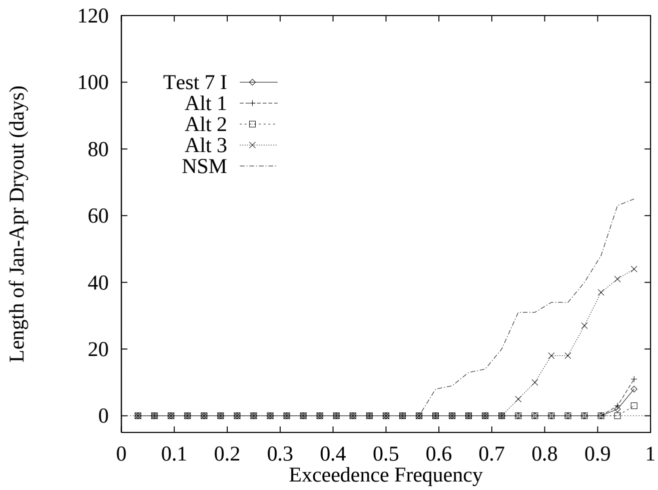


Figure 208: Annual exceedence frequency for the maximum number of days of continuous dryout between January 1 and April 30 for Southern WCA 3A (Indicator Region 14).

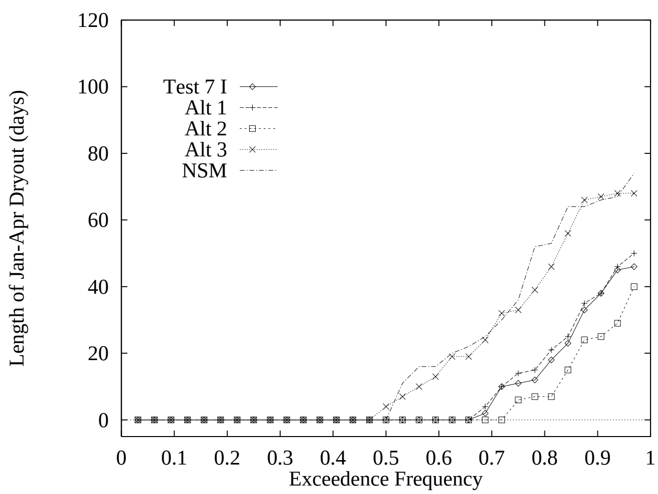


Figure 209: Annual exceedence frequency for the maximum number of days of continuous dryout between January 1 and April 30 for South Central WCA 3A (Indicator Region 17).

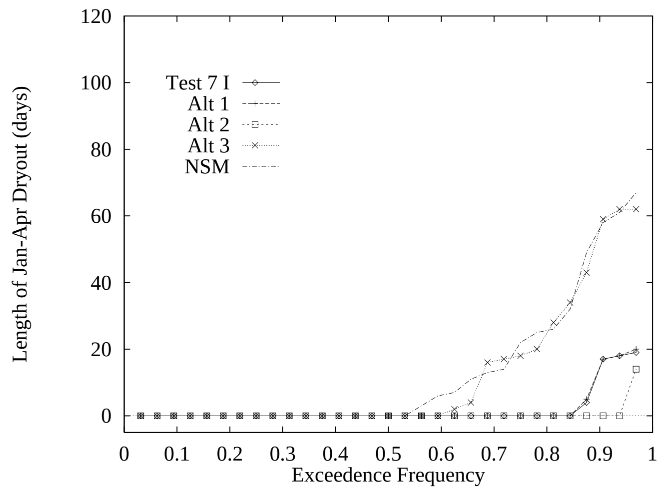


Figure 210: Annual exceedence frequency for the maximum number of days of continuous dryout between January 1 and April 30 for Southern WCA-3A Snail Kite Habitat.

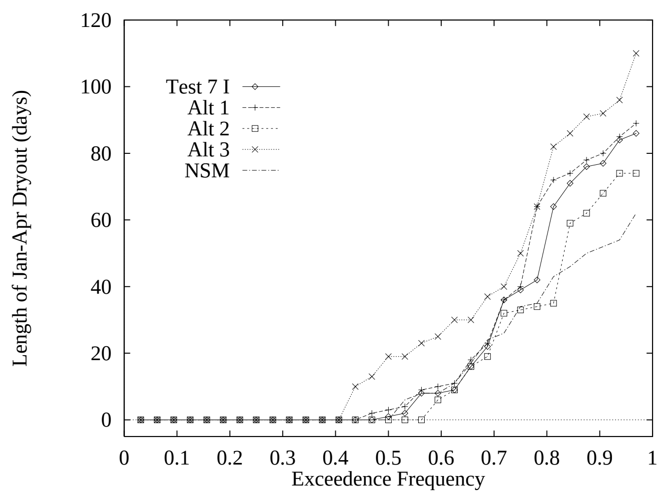


Figure 211: Annual exceedence frequency for the maximum number of days of continuous dryout between January 1 and April 30 for Western WCA-3A Snail Kite Habitat.

A.3 Modified Water Deliveries

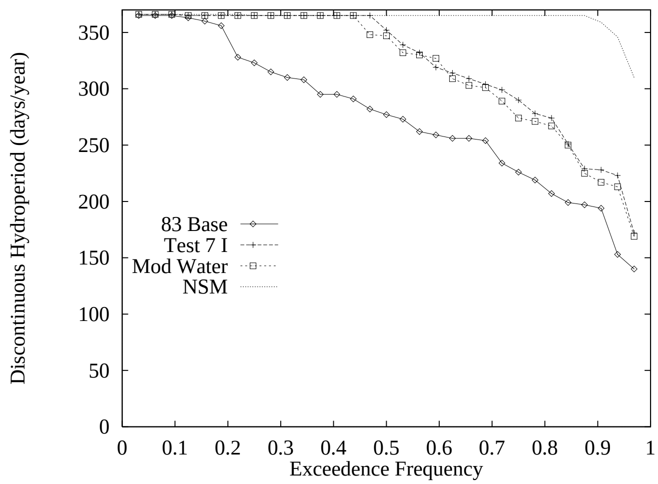


Figure 212: Hydroperiod frequencies for NE Shark River Slough (Indicator Region 11).

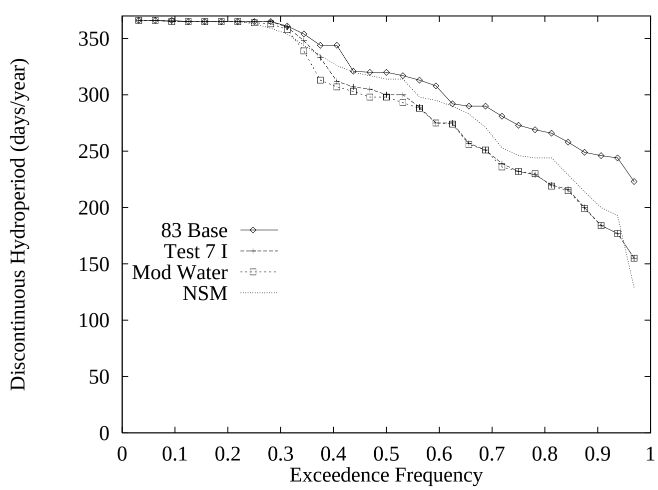


Figure 213: Hydroperiod frequencies for NW Shark River Slough (Indicator Region 12).

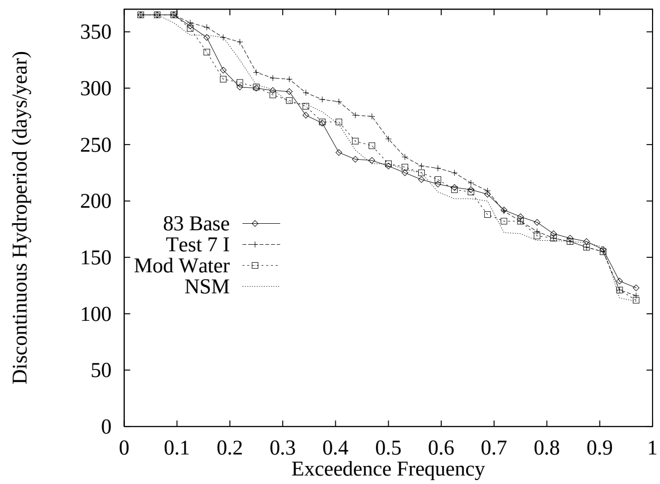


Figure 214: Hydroperiod frequencies for East Slough (Indicator Region 13).

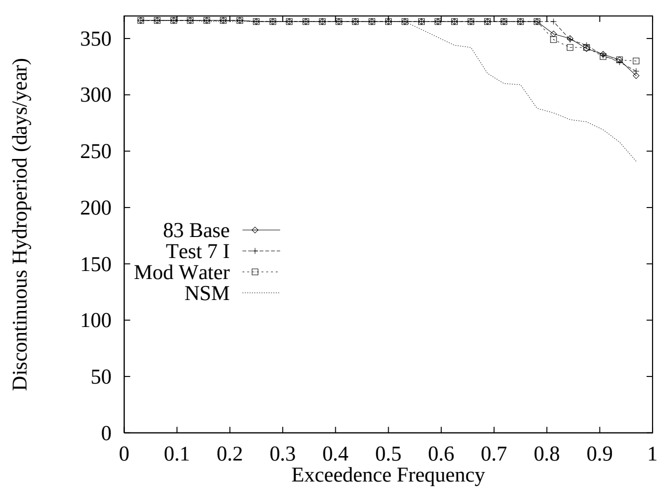


Figure 215: Hydroperiod frequencies for Southern Water Conservation Area 3A (Indicator Region 14.)

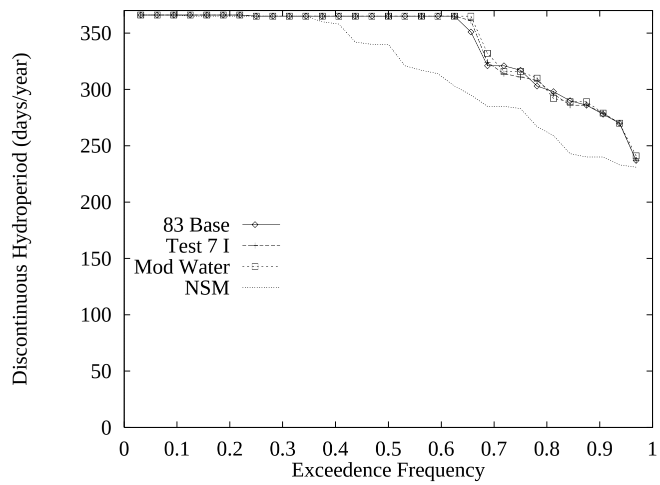


Figure 216: Hydroperiod frequencies for South Central Water Conservation Area 3A (Indicator Region 17.)

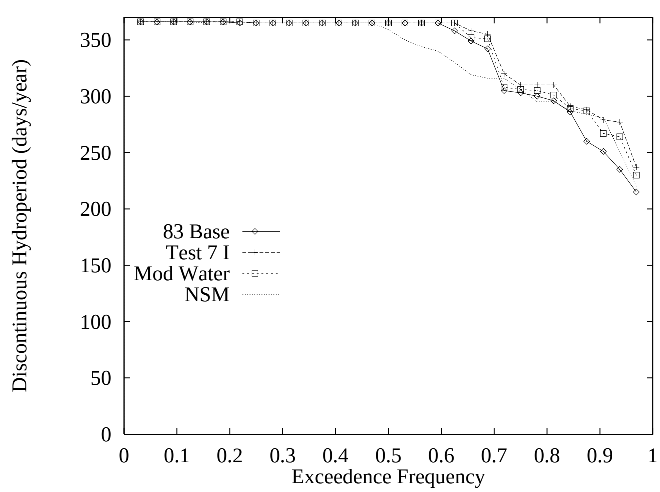


Figure 217: Hydroperiod frequencies for West Water Conservation Area 3B (Indicator Region 15.)

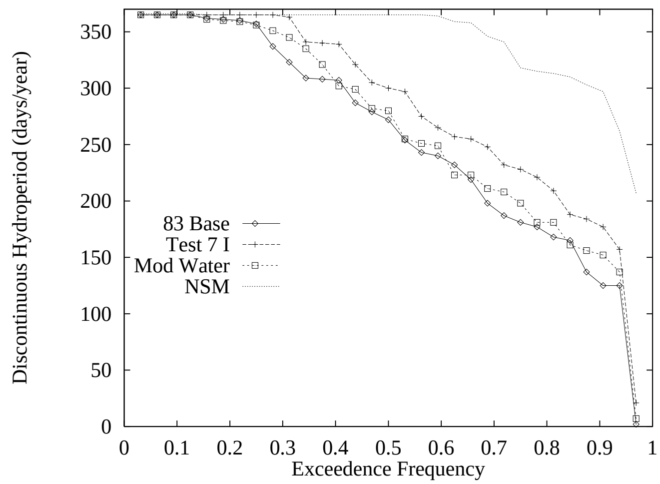


Figure 218: Hydroperiod frequencies for East Water Conservation Area 3B (Indicator Region 16.)

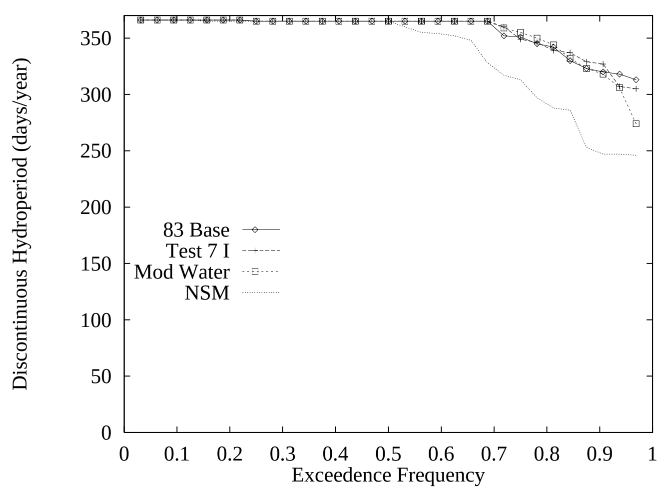


Figure 219: Hydroperiod frequencies for Southern WCA-3A snail kite habitat.

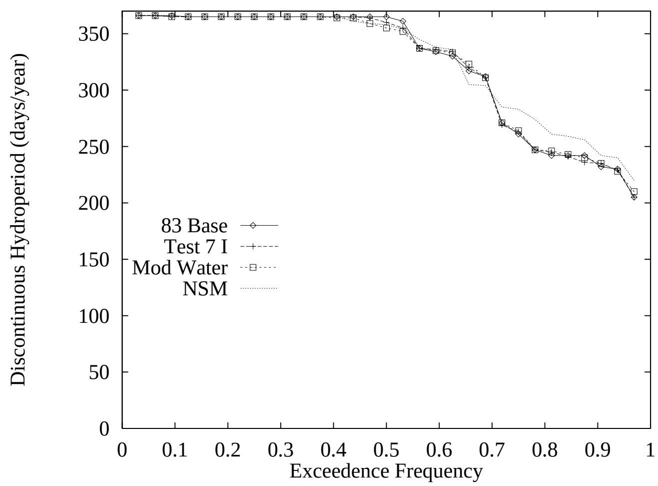
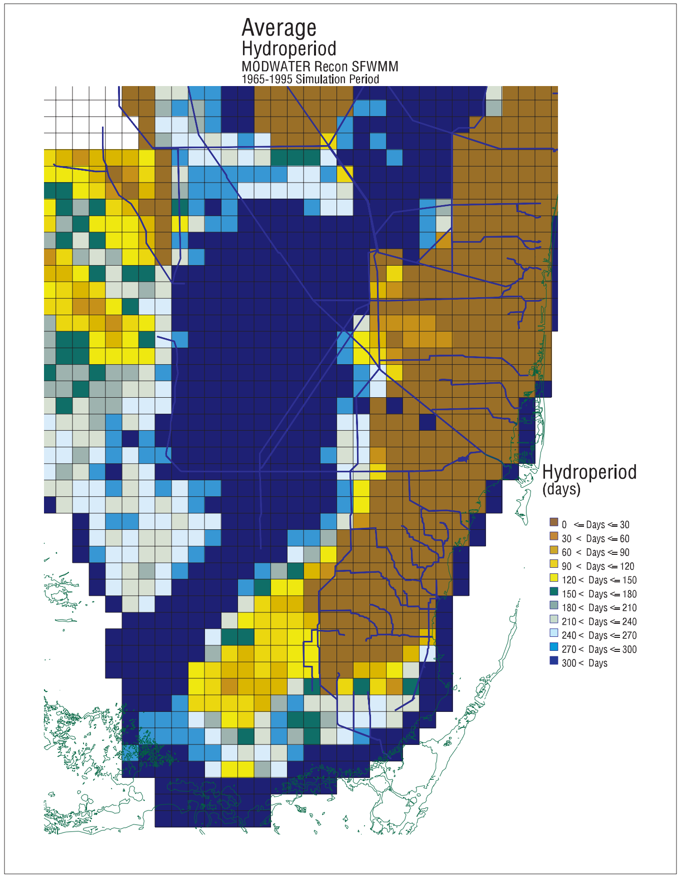
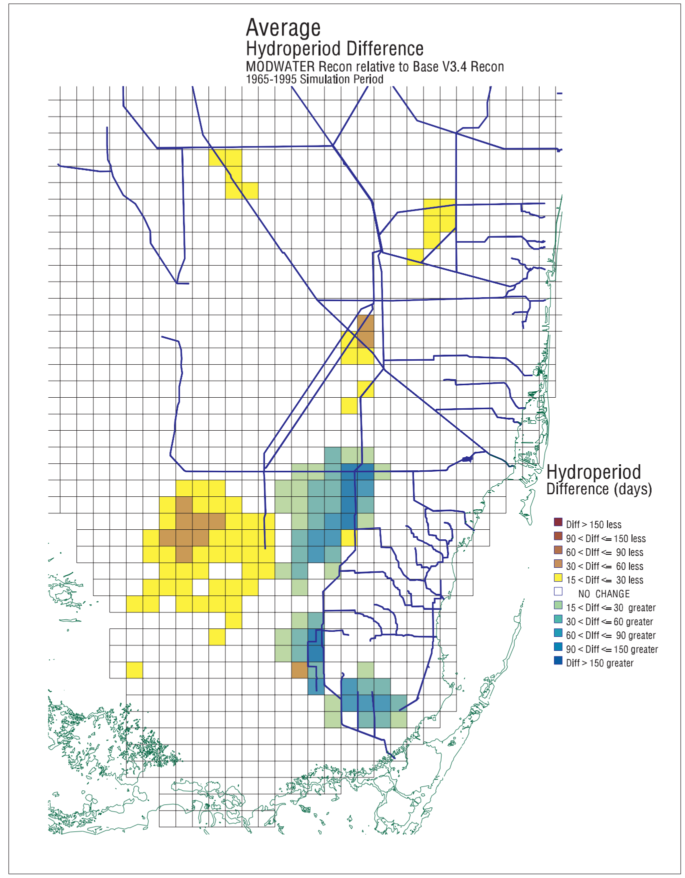


Figure 220: Hydroperiod frequencies for Western WCA-3A snail kite habitat.



(a) Modified Water Deliveries/C-111 Projects



(b) Difference from1983 Base

Figure 221: Average annual hydroperiods predicted for Modified Water Deliveries (including C-111 GRR) and difference from 1983 Base Condition.

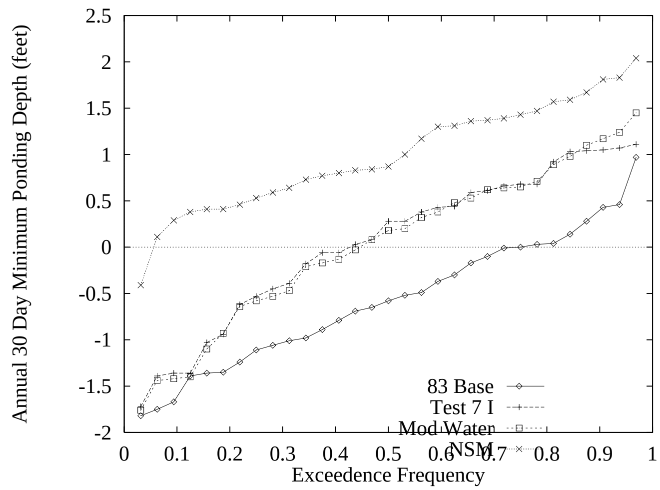


Figure 222: Annual stage exceedence frequency for the 30 Day continuous minimum for North East Shark Slough (Indicator Region 11).

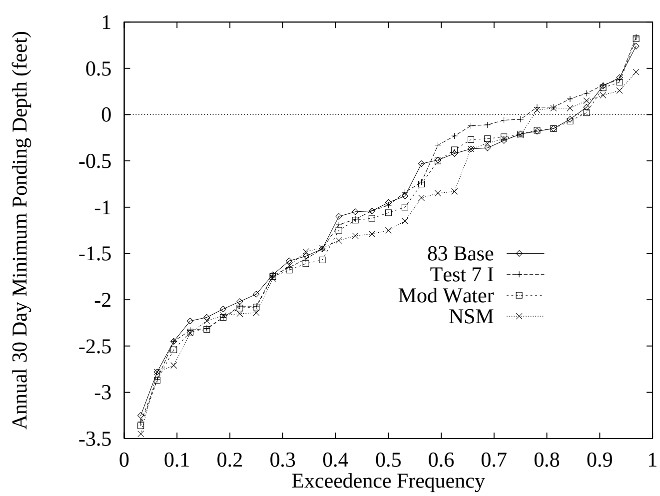


Figure 223: Annual stage exceedence frequency for the 30 Day continuous minimum for East Slough (Indicator Region 13).

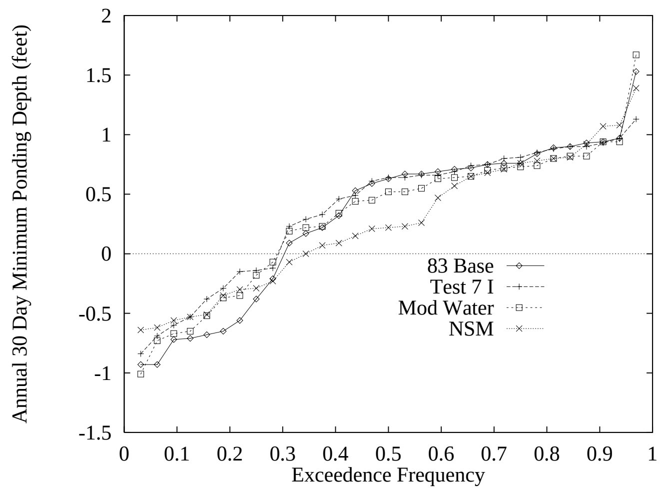


Figure 224: Annual stage exceedence frequency for the 30 Day continuous minimum for West WCA-3B (Indicator Region 15).

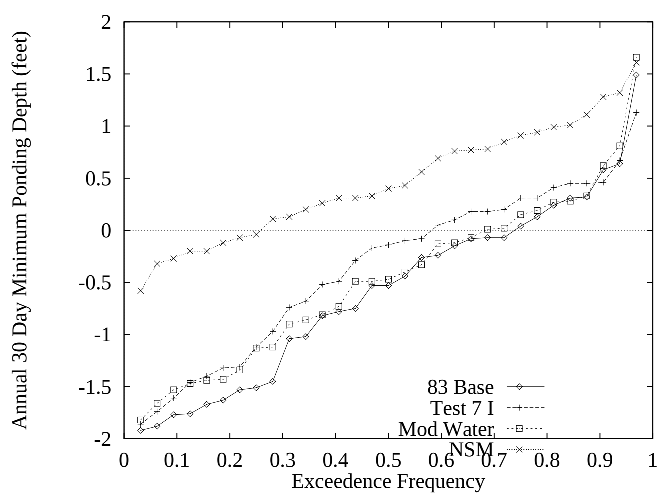


Figure 225: Annual stage exceedence frequency for the 30 Day continuous minimum for West WCA-3B (Indicator Region 16).

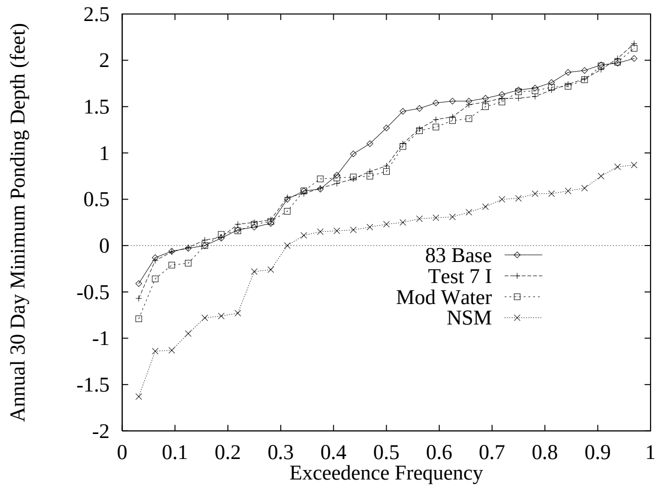


Figure 226: Annual stage exceedence frequency for the 30 Day continuous minimum for Southern WCA-3A Snail Kite Habitat).

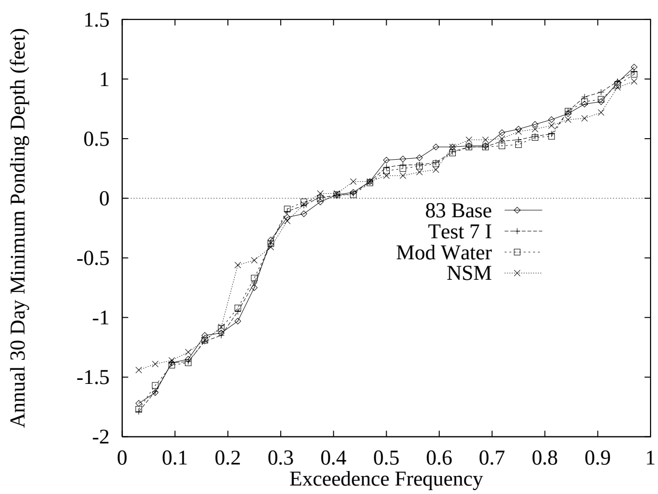


Figure 227: Annual stage exceedence frequency for the 30 Day continuous minimum for Western WCA-3A Snail Kite Habitat.

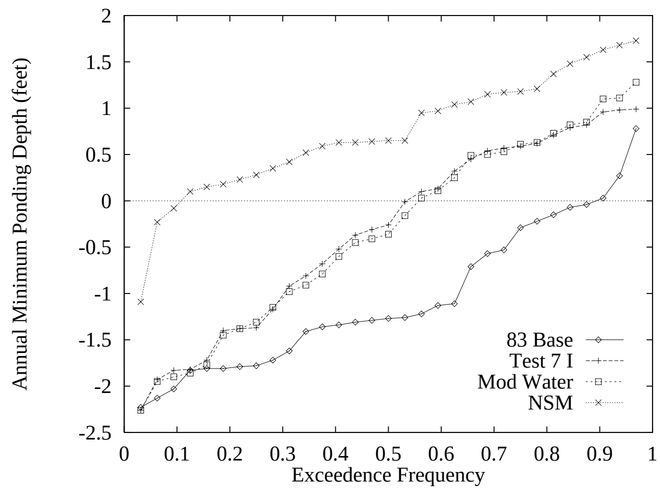


Figure 228: Annual stage exceedence frequency for the minimum for North East Shark Slough (Indicator Region 11).

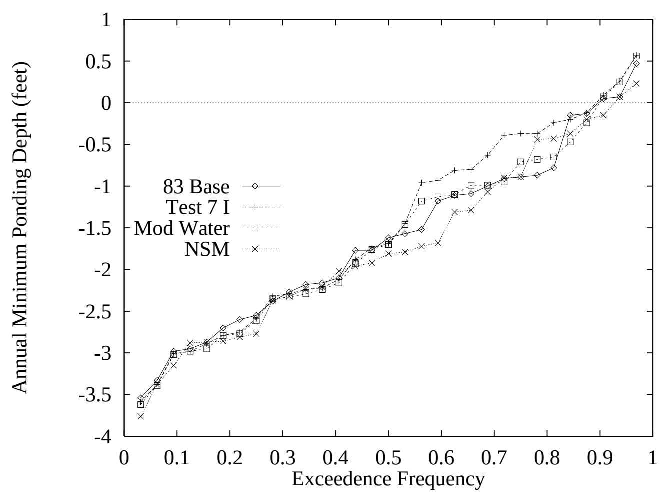


Figure 229: Annual stage exceedence frequency for the minimum for East Slough (Indicator Region 13).

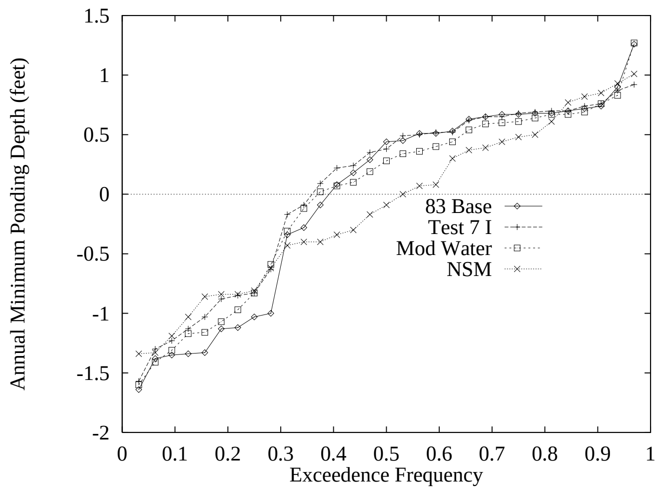


Figure 230: Annual stage exceedence frequency for the minimum for West WCA-3B (Indicator Region 15).

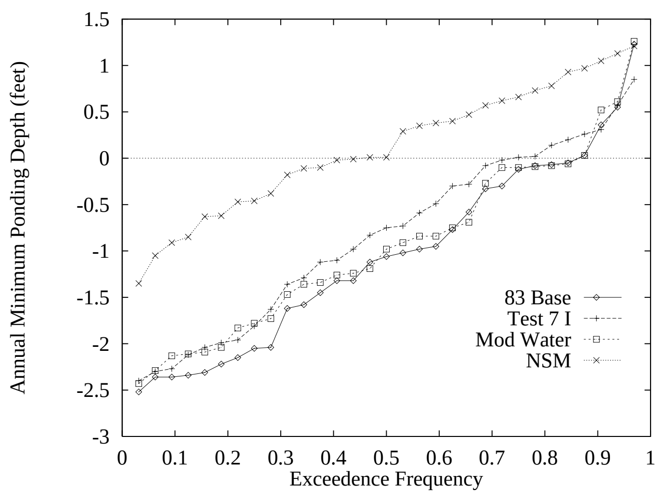


Figure 231: Annual stage exceedence frequency for the minimum for East WCA-3B (Indicator Region 16).

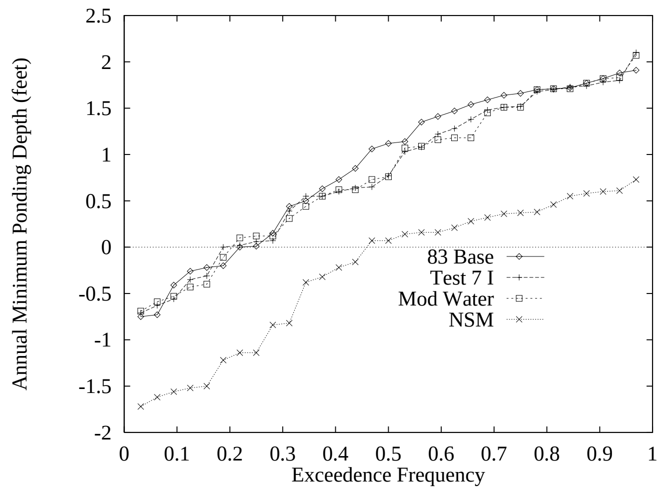


Figure 232: Annual stage exceedence frequency for the minimum for Southern WCA 3A (Indicator Region 14).

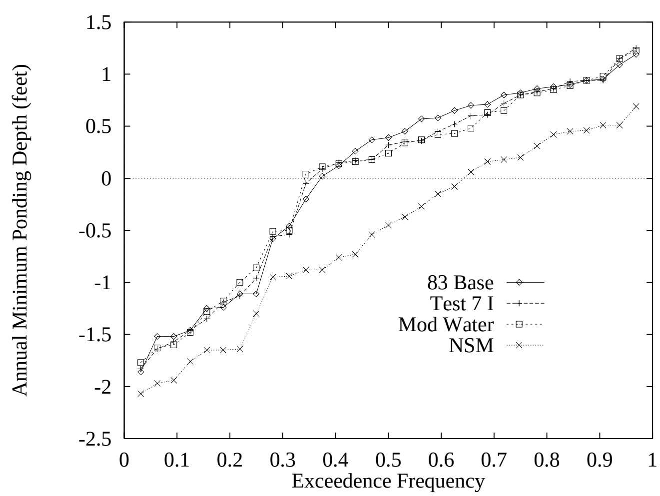


Figure 233: Annual stage exceedence frequency for the minimum for South Central WCA 3A (Indicator Region 17).

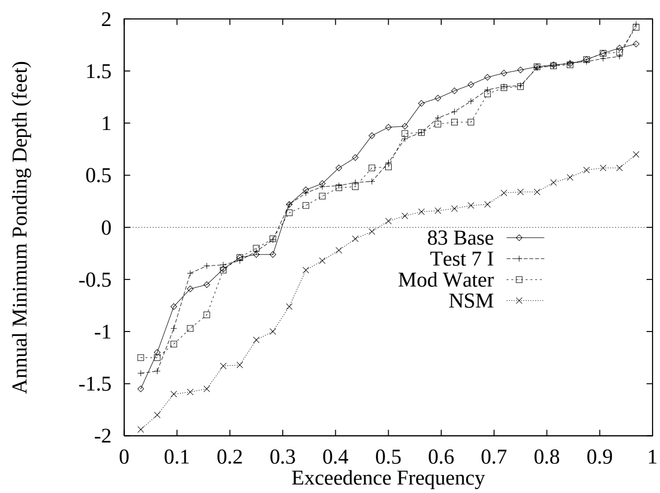


Figure 234: Annual stage exceedence frequency for the minimum for Southern WCA-3A Snail Kite Habitat.

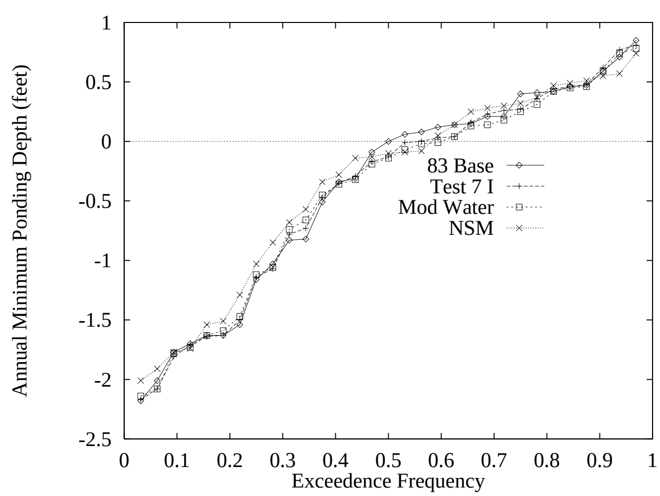


Figure 235: Annual stage exceedence frequency for the minimum for Western WCA-3A Snail Kite Habitat.

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